Vol. XII. — No. 10. October 1930.

BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS

ASSOCIATION

(ENGLISH EDITION)

[625. 113]

RAILWAY CURVES.

Diagrams of versines and superelevations, (1)

by J. CHAPPELLET,

Divisional Inspector in the Headquarters Permanent Way Office of the French Nord Railway Company, Member of the Society of Civil Engineers of France.

Figs. 1 to 58, pp. 2007 to 2037.

Introduction.

The setting out of curves by means of ranging rods and instruments does not give a sufficient degree of accuracy to ensure that the rails are laid with that exactness of curvature which is desirable for trains travelling at high speeds. This method does not eliminate the irregularities of curvature which cause shocks of a damaging nature to the road and the rolling stock and which disturb the comfort of the passengers.

It is consequently no longer generally used except to obtain a provisional pegging out which enables the versines to be measured and subsequently adjusted in order to obtain, according to circumstances, a succession of versines either equal to one another or having a suitable progressive variation (2).

This adjustment, to be reliable, obviously requires a knowledge of the versine diagrams corresponding to the curves utilised to connect straight alignments. Engineers who have studied the method of adjusting curves by the correction of versines have not concerned themselves with this question.

Such an omission is astonishing, for this new technique would have been less suspect and more readily accepted at its inception if its introduction had been preceded by these versine diagrams. Moreover, an acquaintance with them justifies, for example, the non-rectification of certain diagrams which, although of irregular appearance represent correct alignment.

The method is indispensable for drawing correctly diagrams of curvature and hence of superelevation; and also for calculating the levels of groups of track appliances (points, crossings, etc.) to be laid in curves defined by their versine diagrams. Finally, it is very useful for distributing short rails in curves and for

(1) Translated from the French.

(2) See : *Bulletin of the International Railway Congress Association* (May 1928) and *Méthodes de rectification du tracé des courbes de chemins de fer par correction des flèches*. (Methods of ajusting railway curves by the correction of versines), by J. CHAPPELLET. — L. Eyrolles, Publisher, Paris.

calculating the obliquity at each joint, particularly when sections of permanent way are assembled in the shops and are subsequently to be placed in position by means of mechanical contrivances (1).

It appears of interest, therefore, to examine in this article versine diagrams for circular curves and parabolic transition curves, and to show how to determine the geometrical features of an alignment of which only the versine diagram is known and how to draw the diagram of superelevation therefrom.

CHAPTER I.

Various alignments and their corresponding versine diagrams.

Circular curves.

Firstly versine diagrams for circular curves will be dealt with and afterwards those for parabolic transition curves.

a) *Versines diagram referring to the approaches to the point where a circular curve joins directly with a straight line; the point of contact of the circle with the straight line coincides with a peg.*

Let the circular arc AX, of a radius R, be tangential at A to the straight line AY (fig. 1).

When the tangent point A coincides with a peg, the versine at the peg is, without appreciable error, equal to

$$f_A = AD = \frac{BC}{2} = \frac{f}{2} \qquad (1)$$

(f being the versine of the circular arc for a chord AE equal to two lengths d).

(1) See : *Répartition des rails courts employés dans les courbes circulaires et le raccordement parabolique de chemins de fer* (Distribution of short rails used in circular curves and parabolic transition curves), by J. CHAPPELLET. Dunod, Publisher, Paris.

Therefore, the versine diagram corresponding to a circular arc meeting a straight line tangentially is that shown in figure 2, and vice-versa this diagram represents a circular arc meeting a straight line at the tangent point A, if the diagram of curvature is a straight line drawn parallel to the axis of abscissæ, at a distance of $\frac{1}{R}$ and starting from the ordinate of the point A.

Let the circular arc AX be described about the point A in an anti-clockwise direction (fig. 3). The point B coming to B_1, the versine f_A at the peg A is greater than $AD = \frac{f}{2}$; the circular arc AX cuts the straight line in A making with it an angle α, whose tangent is equal to

$$\frac{OM}{OA} = \frac{B_1B}{d} = \frac{2DD_1}{d} = \frac{2}{d}\left(f_A - \frac{f}{2}\right).$$

The versine diagram of this alignment is shewn in figure 4.

When $f_A = f$, the circular arc AX cuts the straight line at an angle α whose tangent is very approximately equal to

$$\frac{2}{d}\left(f - \frac{f}{2}\right) = \frac{f}{d} = \frac{d^2}{2Rd} = \frac{d}{2R}.$$

In this case the versine diagram obtained is represented by figure 5.

As the circular arc AX continues to turn, the versine f_A becomes greater than f and the versine diagram is that of figure 6.

If the rotation of the circular arc AX about the point A takes place in a clockwise direction, the versine f_A becomes smaller than AD, this arc cuts the straight

(1) In practice the arc strikes the straight line between A and C, figure 3, making a projecting angle with AC.

Figs. 1 to 8.

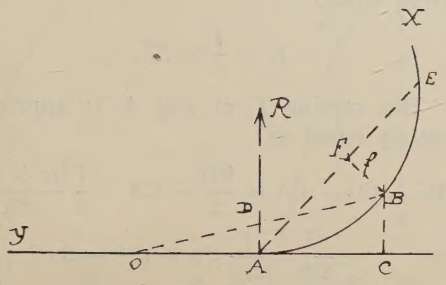


Fig. 1.

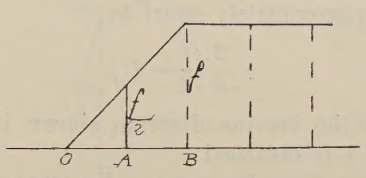


Fig. 2.

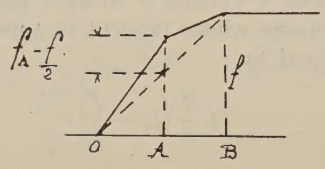


Fig. 4.

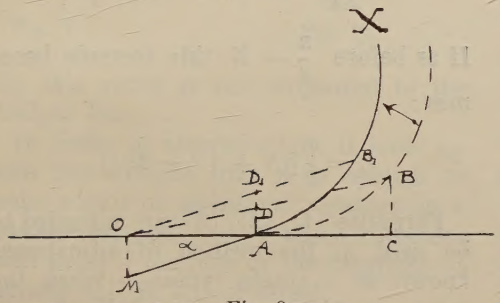


Fig. 3.

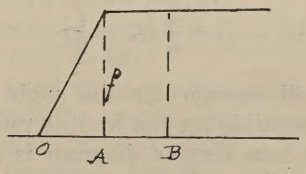


Fig. 5.

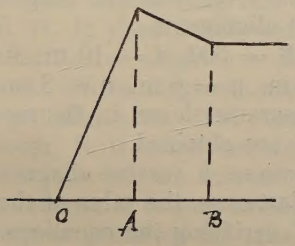


Fig. 6.

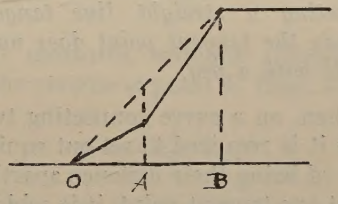


Fig. 7.

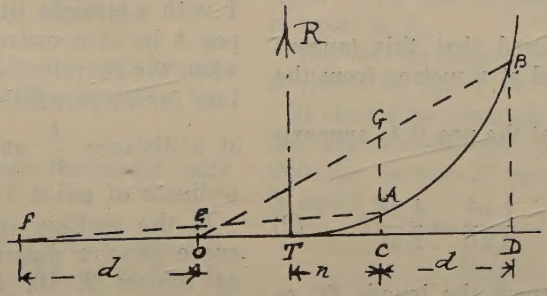


Fig. 8.

line at a re-entrant angle whose tangent is approximately equal to

$$\frac{2}{d}\left(\frac{f}{2} - f_A\right)$$

and the versine diagram shown in figure 7 is obtained.

Vice-versa the versine diagrams of figures 4, 5, 6, 7 represent a circular arc of radius R cutting a straight line at A, at an angle whose tangent is approximately equal to

$$\pm \frac{2}{d}\left(f_A - \frac{f}{2}\right).$$

These versine diagrams are only acceptable if the expression

$$+ \frac{2}{d}\left(f_A - \frac{f}{2}\right)$$

is small enough for the angle α to be imperceptible on the line of rails.

The best versine diagram is evidently that of figure 2.

b) *Versine diagram for a circular arc meeting a straight line tangentially when the tangent point does not coincide with a peg.*

When, on a curve connecting two tangents it is required to set out equidistant pegs (d being their distance apart) starting at one tangent point, it is seldom that the other tangent point coincides with a peg.

Let it be assumed that this tangent point T is situated at n metres from the peg A (fig. 8).

The versine f_o at the peg O is approximately equal to

$$OE = \frac{CA}{2} = \frac{1}{2}\frac{n^2}{2R} = \frac{1}{2}\frac{n^2}{d^2} f \qquad (2)$$

but $\frac{n}{d} = N$ measures the length TC as a multiple of the interval between pegs, from which

$$f_o = \frac{f}{2} \times N^2.$$

The versine f_A at peg A is approximately equal to

$$AG = CG - CA = \frac{BD}{2} - CA = \frac{1}{2}\frac{(n+d)^2}{2R} - \frac{n^2}{2R} = \frac{f}{2d^2}[(n+d)^2 - 2n^2]$$

$$= \frac{f}{2}\left[\left(\frac{n+d}{d}\right)^2 - 2\left(\frac{n}{d}\right)^2\right]. \qquad (3)$$

If as before $\frac{n}{d} = N$, this formula becomes :

$$f_A = \frac{f}{2}[(N+1)^2 - 2N^2].$$

Formulas (1), (2), (3), are intended to be used in the method of adjustment known as « single radius » when the curve, containing no parabolic transitions, is a circular arc tangent to two straight alignments.

For R = 500, d = 10 m., n = 2 m., n = 4 m., n = 6 m., n = 8 m., the versine diagrams shown in figures 9, 10, 11 and 12 are obtained.

Vice-versa, a versine diagram similar to the last ones, the value of the versines f_o, f_A, f, verifying the equations 2 and 3, represents an arc of a circle tangential at T with a straight line and such that the peg A be at n metres from the point T, when the curvature diagram is a straight line drawn parallel to the abscissæ axis, at a distance $\frac{1}{R}$ and starting from the ordinate of point T.

If the plotting of the versines of a curve gives a diagram similar to those of figures 9, 10, 11, 12, the versines f_o f_A, f not satisfying equations (2) and

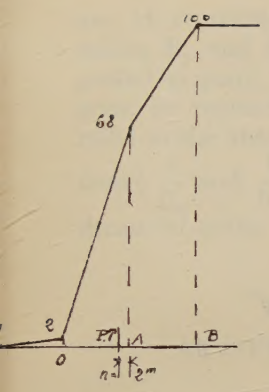


Fig. 9.

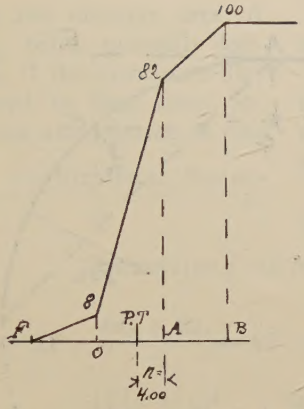


Fig. 10.

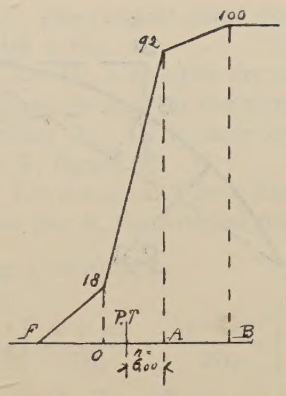


Fig. 11.

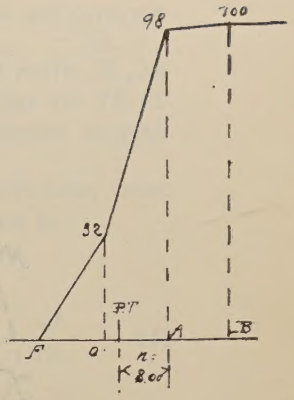


Fig. 12.

(3) this curve is not tangential to the straight line.

In order to ascertain how it joins up with the straight line, it is enough to make a plot of additional versines on a number of pegs, one of which coincides with point T and one of the diagrams of figures 4, 5, 6, 7 is obtained.

Note. — The versine diagrams of figures 9, 10, 11, 12 show bends which are not irregularities as might « a priori » be imagined. These diagrams are those of a correct alignment. Far from improving them, it is often necessary to fit them, at one of the extremities of the curve, because it is very seldom that the two tangent points of the latter each coincide with one of the pegs placed at 10-m. (32 ft. 9 3/4 in.) intervals.

c) *Versine diagram for two circular arcs of different radii with connecting tangents.*

1. *The tangent point coincides with a peg.*

Let the circular arc AMX of radius R_1 and the circular arc ANY of radius R_2 be tangential at A to the straight line DE (fig. 13).

The interval AB = AC.

AM = 2AB = AN = 2AC.

The versine at point B is f_1 = DB, and that at C is f_2 = EC.

AD is equal without appreciable error to AE, hence the tangent point A can be taken as the mid-point of DE.

In the trapezium BDEC,

$$AG = \frac{BD + EC}{2},$$

but AG measures, without appreciable error, the versine at point A, from which

$$f_A = \frac{f_1 + f_2}{2}.$$

At points B, M, etc., the versine is equal to f_1, and at points C, N, etc., it is equal to f_2.

The versine diagram of this alignment is shown in figure 14.

It should be observed that the straight line IK extends over two intervals and that the versine at the tangent point A is equal to

$$\frac{f_1 + f_2}{2}.$$

Vice-versa, the versine diagram of fig-

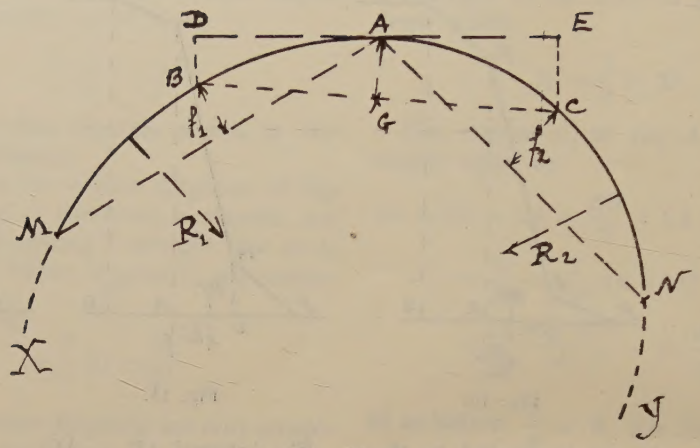


Fig. 13.

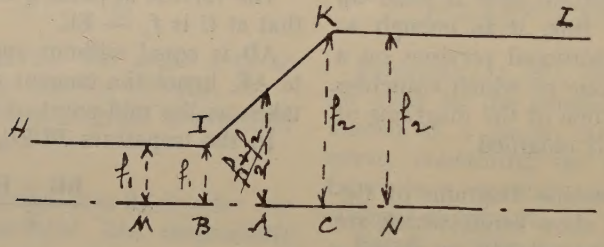


Fig. 14.

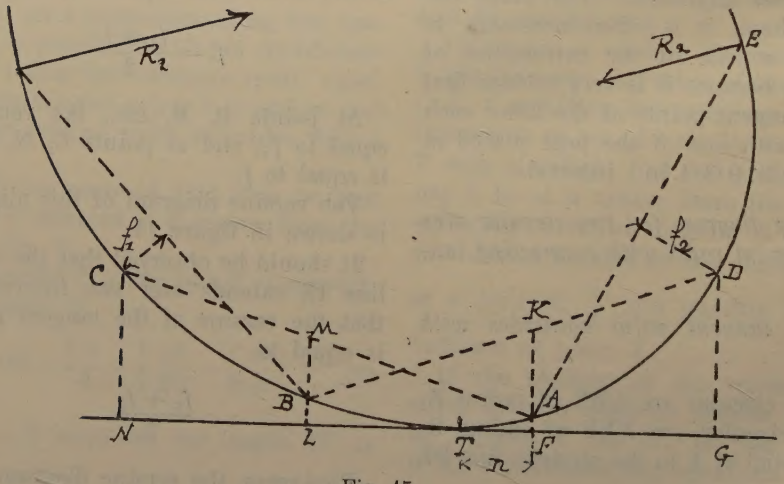


Fig. 15.

ure 14 represents two circular arcs of radius R_1 and R_2, being mutually tangential at point A, if the curvature diagram is represented by two lines parallel to the abscissæ axis, drawn at distances $\frac{1}{R_1}$ and $\frac{1}{R_2}$ starting from the ordinate of point A.

2. *The tangent point does not coincide with a peg.*

Let TC, a circular arc of radius R_1, be tangential at T to the circular arc TE of radius R_2; NG is their common tangent at T, figure 15.

Let the point T be n metres away from the peg A, the interval being d.

The versine f_A at peg A is equal to

$$AK = FK - AF = \frac{DG + BL}{2} - AF = \frac{1}{2}\left[\frac{(d+n)^2}{2R_2} + \frac{(d-n)^2}{2R_1}\right] - \frac{n^2}{2R_2} \qquad (4)$$

$$= \frac{1}{2}\left[\frac{(d+n)^2}{d^2} f_2 + \frac{(d-n)^2}{d^2} f_1\right] - \frac{n^2}{d^2} f_2$$

$$= \frac{1}{2}\left[(1+N)^2 f_2 + (1-N)^2 f_1\right] - N^2 f_2 \text{ if } \frac{n}{d} = N.$$

The versine f_D at points D is equal to f_2, being the versine of the circular arc of radius R_2 for a chord AE equal to two intervals.

The versine f_B at the point B is equal to

$$BM = LM - BL = \frac{CN + AF}{2} - BL = \frac{1}{2}\left[\frac{(d+d-n)^2}{2R_1} + \frac{n^2}{2R_2}\right] - \frac{(d-n)^2}{2R_1} \qquad (5)$$

$$= \frac{1}{2}\left[\left(2 - \frac{n}{d}\right)^2 f_1 + \left(\frac{n}{d}\right)^2 f_2\right] - \left(1 - \frac{n}{d}\right)^2 f_1$$

$$= \frac{1}{2}\left[(2-N)^2 f_1 + N^2 f_2\right] - (1-N)^2 f_1.$$

The versine fc at peg C is equal to f_1, being the versine of the circular arc of radius R_1 for a chord equal to two intervals.

For $R_1 = 500$, $R_2 = 1\,000$, $d = 10$ m. and $n = 5$ m., $n = 8$ m., the versine diagrams shown in figures 16, 17 are obtained.

Vice-versa a versine diagram similar to the two last, the value of the versines f_A, f_B, f_1, f_2 verifying the equations (4) and (5), represents two circular arcs of radii R_1 and R_2 mutually tangential at a point T placed n metres away from the peg A, if the curvature diagram is composed of two lines parallel to the abscissæ axis, drawn at distances $\frac{1}{R_1}$ and $\frac{1}{R_2}$, starting from the ordinate of point T.

It would be very useful to calculate and draw versine diagrams of this nature for the commoner radii and different values of n, for the note appearing on page 2009 is applicable to them.

d) *Versine diagrams for two circular arcs, of different radii, which intersect, the point of intersection coinciding with a peg.*

Let the circular arcs AMX of radius R_1

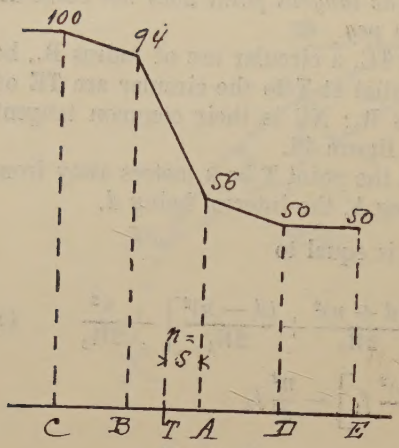


Fig. 16.

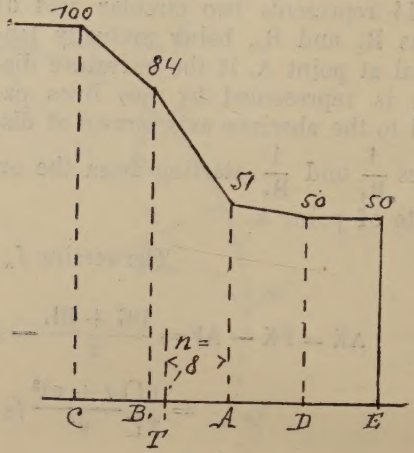


Fig. 17.

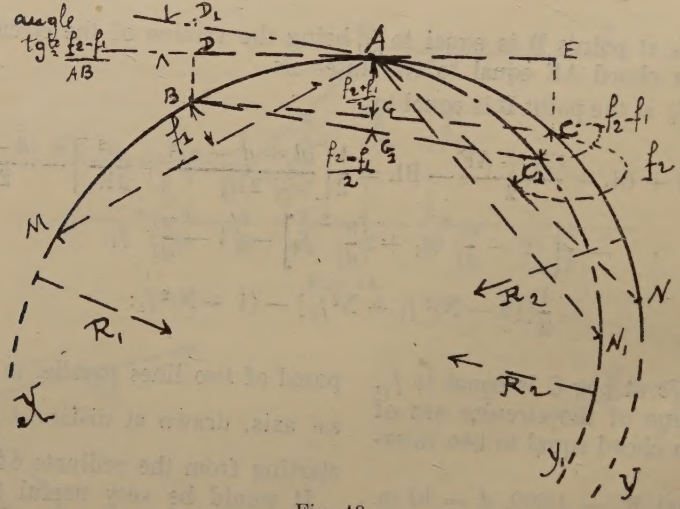


Fig. 18.

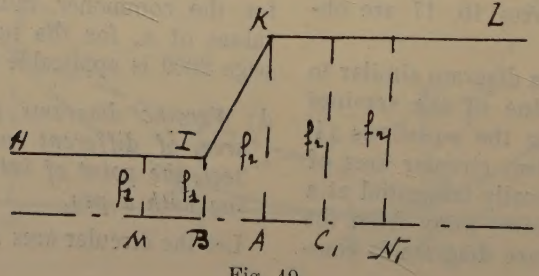


Fig. 19.

and ANY of radius R_2 be tangential at A to the straight line DE (fig. 18).

The interval AB = AC.

AM = 2AB = AN = 2AC.

The versine at point B is f_1 = DB and that at point C is f_2 = EC.

It is known that the versine AG at point A is

$$f_A = \frac{f_1 + f_2}{2}.$$

Let the arc ANY turn into the position $AN_1 Y_1$ so that point C comes to C_1 and $CC_1 = f_2 - f_1$.

Point G has come to G_1 so that, without appreciable error,

$$GG_1 = \frac{CC_1}{2} = \frac{f_2 - f_1}{2},$$

The versine AG_1 at point A is now equal to

$$\frac{f_2}{2} + \frac{f_1}{2} + \frac{f_2}{2} - \frac{f_1}{2} = f_2$$

At points B, M, etc., the versine is equal to f_1, whilst at points C, N, etc., it is equal to f_2.

The versine diagram for this alignment is shown in figure 19.

It is to be noted that the line IK extends over only one interval.

In the rotation of the arc ANY about A, the common tangent AD has come to AD_1 so that $DD_1 = f_2 - f_1$, without appreciable error.

The angle D_1AD is that at which the two arcs AMX and AN_1Y_1 intersect; its tangent is equal to $\frac{f_2 - f_1}{AB}$.

This form of diagram is often met with.

If the difference of the versines f_2 and f_1 is small enough, the interval AB being usually taken at 10 m. (32 ft. 9 3/4 in.), the angle which the two circular arcs make with one another causes no hindrance to the passage of trains. When the arc ANY turns about point A and assumes an intermediate position AN_2Y (not shown) between ANY and AN_1Y_1, point C falls between C and C_1 in a position C_2 (not shown), such that $CC_2 < f_2 - f_1$; point G_1 falls between G and G_1 in a position G_2 (not shown) such that $GG_2 < \frac{f_2 - f_1}{2}$; point D comes to D_2 (not shown) such that $DD_2 < f_2 - f_1$.

Let AG_2 be the new versine at point A; then $AG_2 < AG_1$, from which $AG_2 < f_2$.

Moreover

$$AG_2 = \frac{f_1 + f_2}{2} + GG_2.$$

The versine diagram is shown in figure 20.

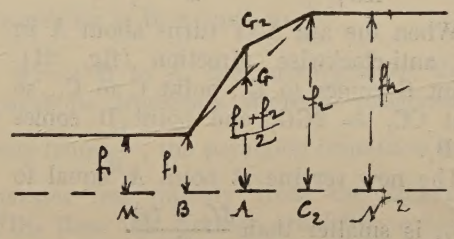


Fig. 20.

For the same reason that $CC_1 = 2GG_1$ and $DD_1 = CC_1$ it follows that

$$CC_2 = 2\,GG_2 = 2\left[AG_2 - \frac{(f_1 + f_2)}{2}\right]$$

since

$$GG_2 = AG_2 - \frac{f_1 + f_2}{2}$$

and

$$DD_2 = CC_2 = 2\left[AG_2 - \frac{(f_1 + f_2)}{2}\right].$$

The angle DAD_2 gives the angle at

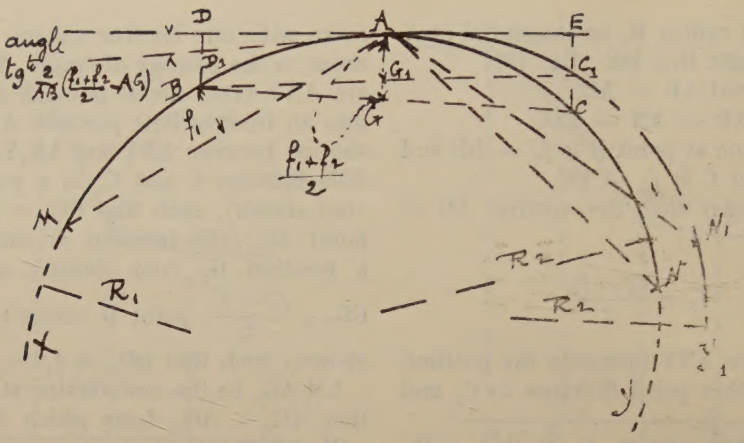


Fig. 21.

Explanation of French terms: Angle = Angle. — tgte = Tangent.

which the circular arcs AMX and AN_2Y_2 intersect, its tangent is equal to

$$\frac{2}{AB}\left[AG_2 - \frac{(f_1 + f_2)}{2}\right].$$

When the arc ANY turns about A in an anti-clockwise direction (fig. 21), point G comes to G_1, point C to C_1, so that $CC_1 = 2GG_1$ and point D comes to D_1.

The new versine at point A, equal to AG_1, is smaller than $\frac{(f_1 + f_2)}{2}$.

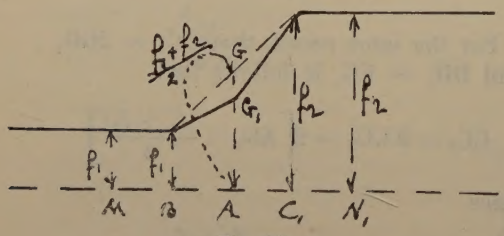


Fig. 22.

The versine diagram appears in figure 22.

$$CC_1 = 2GG_1 = 2\left(\frac{f_1 + f_2}{2} - AG_1\right),$$

$$DD_1 = CC_1 = 2\left(\frac{f_1 + f_2}{2} - AG_1\right)$$

and the angle DAD_1 is that at which the two circular arcs AMX and AN_1Y_1 intersect; its tangent is equal to

$$\frac{2}{AB}\left(\frac{f_1 + f_2}{2} - AG_1\right).$$

This angle is re-entering; it ought always to be very small so as to be inappreciable.

Vice-versa, the versine diagrams of figures 19, 20, 22, are those for two circular arcs of radii R_1 and R_2 intersecting at the point of contact A, when the curvature diagram is composed of two lines parallel to the abscissæ axis, drawn at distances $\frac{1}{R_1}$ and $\frac{1}{R_2}$, therefrom, and starting at the ordinate of point A.

e) *Curves of contrary curvature.*

Here will be considered successive circular arcs without intermediate straights and those which are separated by a straight whose length is not greater than one or two peg intervals.

1. *Successive curves without an intermediate straight* (fig. 23). — The point T, where the curvature changes in sense, is determined exactly by the usual method. Next the tangents TF and TE to each

curve passing through T are drawn. If these tangents are collinear, the curves are mutually tangential, otherwise they intersect. In this case the pegs F and E are placed in the line of one of the tangents and where the versine is zero.

Then each curve is adjusted separately, after having set out the versines in such a manner that the point of inflection T coincides with a peg.

2. *The two curves separated by a very short straight.* — The straight is produced sufficiently to enable the pegs F and E to be placed where the versine is zero, and each curve is studied by the ordinary methods.

Parabolic transitions of theoretical spirals.

a) *Curvature diagram for a parabolic transition or theoretical spiral when the points where the transition is tangential to the straight and to the circular arc each coincide with a peg.*

A parabolic transition is a curve whose radii of curvature vary continuously from $+\infty$ (radius of curvature at point O where the transition is tangential to the straight) to R (radius of curvature at peg P where the transition is tangential to the circular arc of radius R) (fig. 24).

The curvatures $\frac{1}{R}$ vary also in a continuous manner from $\frac{1}{\infty} = 0$ at the peg *o* to $\frac{1}{R}$ the curvature of the circular arc at peg P, their diagram is a straight line inclined to the abscissæ axis and the curvature $\frac{1}{R_x}$ at a point whose abscissa is x is given by the formula $\frac{1}{R_x} = k\,x$, k being the slope of this straight line.

b) *Versine diagram for a parabolic transition or theoretical spiral when the points where the transition is tangential to the straight and to the circular arc each coincide with a peg.*

The versine of an arc of a parabolic transition is proportional to the curvature of the transition at the middle of the arc.

An arc of a parabolic transition ABC extending over two intervals from $(x - d)$ to $(x + d)$ will be considered.

Let DBE be the circular arc tangential at B to the parabolic transition (fig. 25), and FBG the common tangent at B to the circle and parabolic transition.

If R_x is the radius of the circular arc DBE, the curvature of the parabolic transition at B is equal to $\frac{1}{R_x}$.

From B to A, the curvatures of the parabolic transition decrease progressively from $\frac{1}{R_x}$, the parabolic transition separates less quickly from the tangent FBG than the circular are DBE; consequently, FA is less than FD; from B to C the curvatures of the parabolic transition increase progressively from $\frac{1}{R_x}$, the parabolic transition separates more quickly from the tangent FBG than the circular arc DBE; consequently, GC is greater than GE and the circular arc DBE crosses the parabolic arc at B (1).

---

(1) This results, moreover, in that the third derivatives of the equations to the osculatory circular arc and to the parabolic transition are not equal, the first being zero and the second equal to $\frac{1}{2pR}$.

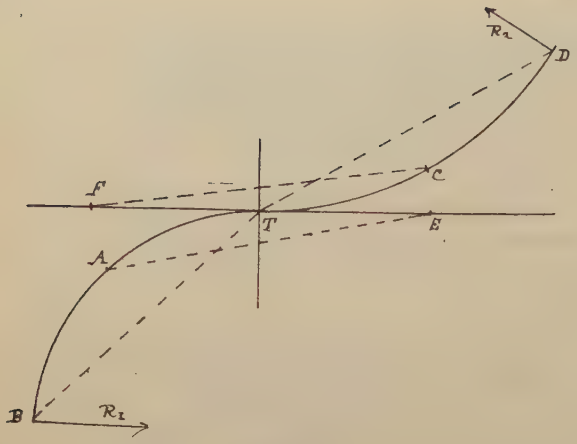


Fig. 23.

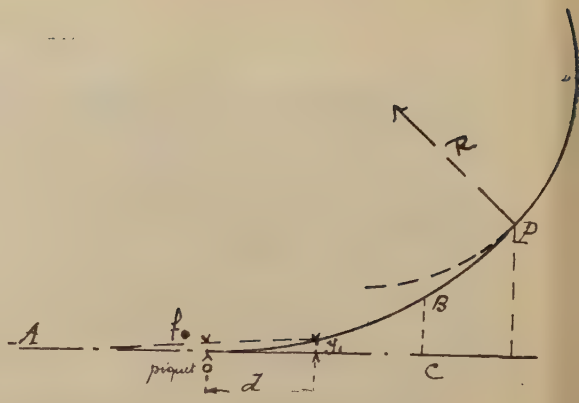


Fig. 24.

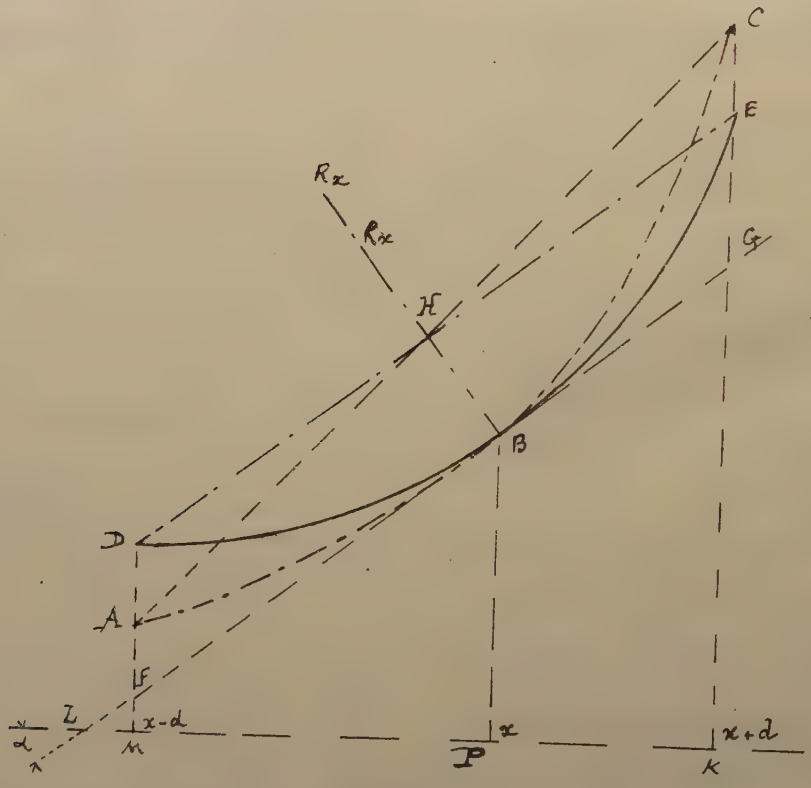


Fig. 25.

Explanation of French term: Piquet = Peg.

Moreover, AD = CE since the variations of curvature are equal at every point.

CE will now be calculated.

When point B is considered as belonging to the parabolic transition, $PB = \frac{x^3}{12pR}$ and the straight line FG produced makes at L with the abscissæ axis. an angle α whose tangent is equal to the derivative $\frac{dy}{dx}$ of $\frac{x^3}{12pR}$, hence

$$\tan\alpha = \frac{3x^2}{12pR} = \frac{x^2}{4pR},$$

which gives

$$LP = \frac{BP}{\operatorname{tg}\alpha} = \frac{\frac{x^3}{12pR}}{\frac{x^2}{4pR}} = \frac{x}{3},$$

from which

$$LK = \frac{x}{3} + d$$

and

$$LM = \frac{x}{3} - d,$$

also

$$EC = GC - GE, \qquad GC = KC - KG,$$

$$KC = \frac{(x+d)^3}{12pR} = \frac{x^3+d^3+3x^2d+3d^2x}{12pR},$$

$$KG = LK\tan\alpha = \left(\frac{x}{3}+d\right)\frac{x^2}{4pR}$$

$$= \frac{x^3}{12pR} + \frac{x^2d}{4pR} = \frac{x^3+3x^2d}{12pR},$$

from which

$$GC = \frac{x^3+d^3+3x^2d+3d^2x-x^3-3x^2d}{12pR} = \frac{3d^2x+d^3}{12pR}.$$

Without appreciable error

$$GE = \frac{\overline{BG}^2}{2R_x} = \frac{d^2}{2R_x}$$

but

$$R_x\,(1) = \frac{1}{\frac{x}{2pR}} = \frac{2pR}{x}$$

from which

$$GE = \frac{d^2}{\frac{4pR}{x}} = \frac{d^2x}{4pR} = \frac{3d^2x}{12pR}$$

and $GE < GC$.

Consequently

$$EC = \frac{3d^2x+d^3}{12pR} - \frac{3d^2x}{12pR} = \frac{d^3}{12pR}.$$

Calculating DA,

we get $AD = FD - FA \quad FA = AM - FM$

$$AM = \frac{(x-d)^3}{12pR} = \frac{x^3-d^3-3x^2d+3xd^2}{12pR},$$

$$FM = LM\tan\alpha = \left(\frac{x}{3}-d\right)\frac{x^2}{4pR}$$

$$= \frac{x^3}{12pR} - \frac{x^2d}{4pR} = \frac{x^3-3x^2d}{12pR}$$

and

$$FA = \frac{x^3-d^3-3x^2d+3xd^2-x^3+3x^2d}{12pR} = \frac{3xd^2-d^3}{12pR}.$$

---

(1) We get

$$y = \frac{x^3}{12pR}, \quad \frac{dy}{dx} = \frac{x^2}{4pR}, \quad \frac{d^2y}{dx^2} = \frac{x}{2pR}$$

and without appreciable error

$$R_x = \frac{1}{\frac{d^2y}{dx^2}} = \frac{1}{\frac{x}{2pR}}.$$

Without appreciable error,

$$FD = \frac{\overline{FB}^2}{2R_x} = \frac{d^2}{2R_x} = \frac{d^2}{\frac{4pR}{x}} = \frac{xd^2}{4pR} = \frac{3xd^2}{12pR}$$

and FA < FD as was expected.

Consequently

$$AD = \frac{3xd^2 - 3xd^2 + d^3}{12pR} = \frac{d^3}{12pR}$$

and

$$CE = AD = \frac{d^3}{12pR} (1).$$

Now let the chords DE of the circular arc and AC of the parabolic transition be considered. These two chords intersect at their mid-points since CE = AD and HB measures, to a sufficient degree of accuracy, the versine of the osculatory circular arc DBE and that of the arc of the parabolic transition ABC.

We get :

$$HB = \frac{d^2}{2R_x} = \frac{d^2}{2} \times \frac{1}{R_x}$$

and the versine of an arc ABC of parabolic transition corresponding to a chord AC is proportional to the curvature of the transition at the middle of the arc ABC.

The versine diagram of a parabolic transition is, therefore, a straight line inclined to the abscissæ axis and the versine f_x at a point whose abscissa is x on the transition is given by the equation $f_x = k_x$, k being the slope of this straight line (fig. 26).

When taking the versines of a parabolic transition, it is noticed that the versine f_o at peg O (fig. 24), where the parabolic transition is tangential to the straight alignment, is not zero and that the versine f_p at peg P, where the parabolic transition is tangential to the circular arc of radius R, is not equal to the versine f_R of the latter for the same chord.

Let f_o now be calculated.

Let o P be a parabolic transition tangential to the straight alignment AB at peg O (fig. 24). The versine f_o at peg O is equal, without appreciable error, to half the ordinate y_1, of peg 1.

If in the equation of the parabolic transition, $y = \frac{x^3}{12pR}$, x is made equal to d, it follows that

$$y_1 = \frac{d^3}{12pR} \text{ et } f_o = \frac{y_1}{2} = \frac{d^3}{24pR}.$$

Previously it has been found that CE $= AD = \frac{d^3}{12pR}$, therefore CE $= AD = y_1$; this is easily explained by the fact that the straight line AB may be regarded as a circle of infinite radius meeting the parabolic transition tangentially at O, and that, at the extremity of each interval, the transition always deviates by the same amount $\frac{d^3}{12pR}$ from the circle which is tangential to it at the beginning of each interval.

Let f_p now be calculated.

Let the parabolic transition MAP which is tangential at P to the circular arc PC of radius R be now considered (fig. 27).

On either side of point P, take PC = PA = PD = d (the length of the interval).

(1) The ordinates calculated from the equation

$$y = \frac{x^3}{12pR}$$

can always be referred to an osculatory circular arc, the origin of abscissæ being the point of osculation, the straight alignment being, moreover, an osculatory circle of radius ∞.

Let chords AC and DC be considered.

The versine f_p of the parabolic transition at P is equal to PE; f_R, that of the circle of radius R, is equal to PG.

Then

$$PE = PG - GE = f_R - GE.$$

But

$$GE = \frac{AD}{2} = \frac{1}{2}\frac{d^3}{12pR} = \frac{d^3}{24pR}$$

and

$$PE = f_p = f_R - \frac{d^3}{24pR}.$$

The diagram of versines obtained after perfect pegging out of a theoretical parabolic transition is then represented by figure 28.

Note that the straight line FI produced meets the abscissæ axis at point O and the horizontal line AB at the end of the pth ordinate.

From what has been written above, see paragraph *a*), the curvature diagram is the straight line OB, when the scale of curvatures is suitably chosen.

Conversely a diagram of versines similar to that of figure 28 represents a theoretical parabolic transition, when the curvature diagram is the straight line OB (the scale of curvatures being suitably chosen), if

$$f_o = \frac{d^3}{24pR} \text{ et } f = f_R - \frac{d^3}{24pR}.$$

c) *Equation to theoretical parabolic transitions, in terms of K, the difference between two successive versines.*

The ordinate BC of a parabolic transition, at peg B situated at a distance x from the origin O, measures the amount of slue to be given to point C in the straight line to bring it on to the curve at peg B. (fig. 24).

The versines of a straight alignment

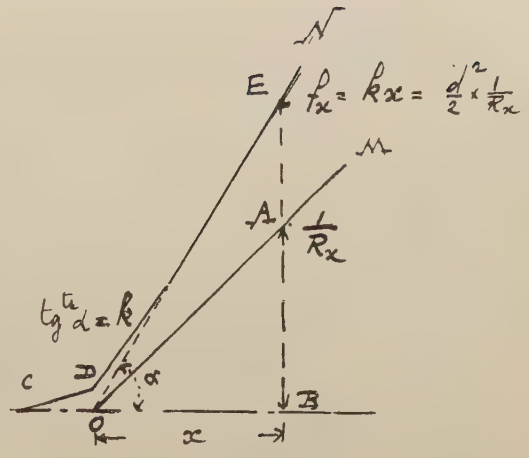


Fig. 26.

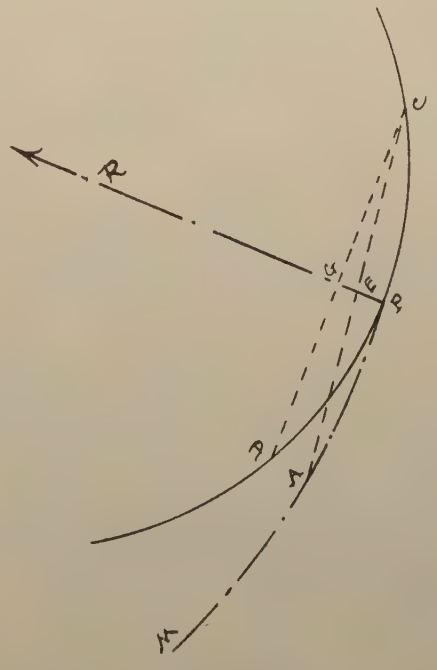


Fig. 27.

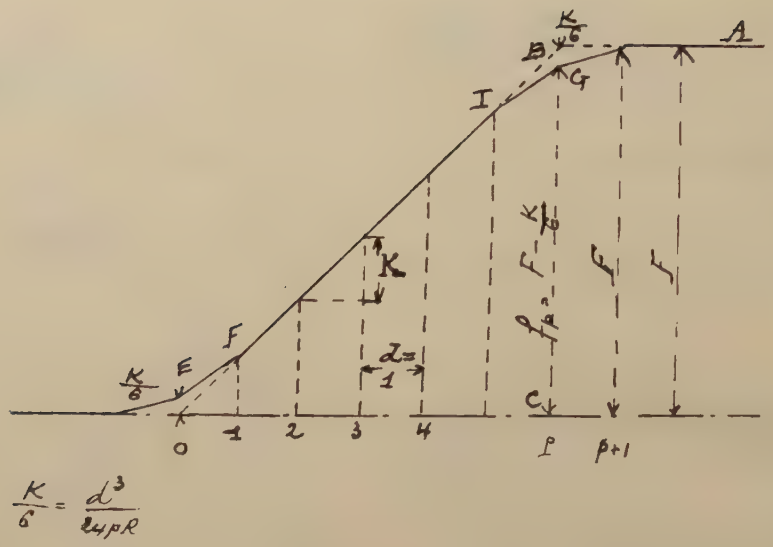


Fig. 28.

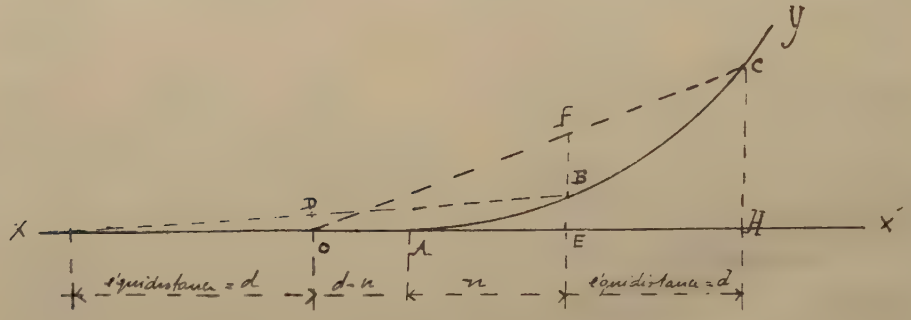


Fig. 29.

Explanation of French term : Equidistance = Equal interval.

being zero, this slue is equal to double the sum of the moments about B of the versines from O to B of the transition.

It has been pointed out that the versine at a point on a parabolic transition situated at a distance x from the origin is equal to

$$\frac{d^2}{2} \times \frac{1}{R_x}.$$

The sum of the moments about B of the versines o to x is equal to the moment of the resultant of these versines about B, considered as forces.

The resultant of the versines, or their sum, is equal to

$$\Sigma_o^x \frac{d^2}{2} \frac{1}{R_x} = \frac{d^2}{2} \Sigma_o^x \frac{1}{R_x}.$$

All depends on the evaluation of $\Sigma_o^x \frac{1}{R_x}$ and its moment about B.

Let OAM be the curvature diagram of the transition under consideration (fig. 26).

At peg B, whose abscissa is x, the curvature is equal to $\frac{1}{R_x}$

The sum $\sum_o^x \frac{1}{R_x}$ of the curvatures is equal to the area of the triangle OAB, or $\frac{1}{2} \cdot \frac{x}{d} \cdot \frac{1}{R_x}$ measuring distance x in multiples of the interval d.

The resultant of the curvatures, considered as forces, obviously passes through the centroid of the triangle OAB, that is to say at $\frac{1}{3}\frac{x}{d}$ from B and its moment about B is equal to

$$B = \frac{1}{2}\frac{x}{d}\frac{1}{R_x}\frac{1}{3}\frac{x}{d} = \frac{1}{2}\frac{1}{3}\frac{x^2}{d^2}\frac{1}{R_x} = \frac{1}{3}\frac{x^2}{d^4} f_x$$

substituting $\frac{2f_x}{d^2}$ for $\frac{1}{R_x}$.

If CDEN is the versine diagram for the parabolic transition,

$$f_x = kX$$

and

$$\frac{1}{3}\frac{X^2}{d^4} f_x = \frac{1}{3}\frac{kX^3}{d^4}.$$

The sum of the moments of the transition from O to B is therefore equal to

$$\frac{1}{3}\frac{kX^3}{d^4}\frac{d^2}{2} = \frac{1}{6}\frac{kX^3}{d^2}$$

and the ordinate BC is equal to

$$BC = Y = 2.\frac{1}{6}\frac{kX^3}{d^2} = \frac{1}{3}\frac{kX^3}{d^2} = \frac{1}{3}\frac{KX^3}{d^3} \quad (6)$$

since $K = kd$.

Calculation of versine f_o at peg O.

The ordinate y_1 at peg 1, whose abscissa is equal to d, has the value :

$$y_1 = \frac{kd^3}{3d^2} = \frac{kd}{3} = \frac{K}{3}$$

whence

$$f_o = \frac{y_1}{2} = \frac{kd}{6} = \frac{K}{6}.$$

It has also been observed (p. 2018) that

$$AD = CE = y_1$$

whence

$$AD = CB = \frac{kd}{3} = \frac{K}{3}.$$

Calculation of versine f_p at peg P.

Now

$$f_p = f_R - \frac{d^3}{24pR}$$

but

$$\frac{d^3}{24pR} = \frac{y_1}{2} = f_o = \frac{K}{6}$$

whence

$$f_p = f_R - \frac{K}{6}.$$

It should be noticed that by compensation the versine f_o, at the tangent point with the straight line, not being zero but equal to $\frac{K}{6}$, the pth versine, at the tangent point with the circular arc, is not equal to $f_R - \frac{K}{6}$.

d) *Diagram of versines and curvatures of a theoretical parabolic transition when the points, where the transition is tangential to the straight line and to the circular arc, do not both coincide with a peg.*

Let the parabolic transition AY be tangential to the straight XX′ at the origin

A (fig. 29), such that A is situated between pegs O and B and at a distance n from peg B.

Calculating the versine f at peg O and versine f_B at peg B,

we get $f_o = OD = \frac{BE}{2}$.

Now the ordinate BE of the transition according to equation (6) is equal to

$$y = \frac{Kn^3}{3d^3}, \text{ whence } f_o = \frac{Kn^3}{6d^3} = \frac{K}{6} N^3 \quad (7)$$

if $N = \frac{n}{d}$ gives length AE in multiples of the interval d.

Also $f_B = BF = EF - EB$, but $EF = \frac{CH}{2}$

whence

$$f_B = \frac{CH}{2} - EB$$

$$CH = \frac{K}{3}\left(\frac{d+n}{d^3}\right)^3 = \frac{K}{3}\left(\frac{d+n}{d}\right)^3 = \frac{K}{3}(1+N)^3$$

$$\frac{CH}{2} = \frac{K}{6}(1+N)^3 \left(N \text{ being equal to } \frac{n}{d}\right)$$

$$EB = \frac{Kn^3}{3d^3} = \frac{K}{3} N^3$$

from which

$$f_B = \frac{K}{6}(1+N)^3 - \frac{K}{3} N^3$$

$$= \frac{K}{6}[(1+N)^3 - 2N^3] \quad (8)$$

Let us consider next the part LPQ of this transition (fig. 30) which is tangential at Q to the circular arc GNT of radius R so that Q is at a distance m from point P.

The versine f_p at peg P is equal to PI = PN + NH — IH, PN is the amount by which the transition PQ withdraws from the circular arc QN, at distance m from the tangent point Q.

The equation to the parabolic transition being $y = \frac{x^3}{12pR}$, PN is equal to $\frac{m^3}{12pR}$ (see page 2018).

Evaluating $12pR$ as a function of K the difference between two successive versines of the transition and of the interval d, this gives

$$y = \frac{x^3}{12pR} = \frac{Kx^3}{3d^3}$$

whence

$$12pR = \frac{3d^3}{K}$$

and

$$PN = \frac{Km^3}{3d^3} = \frac{K}{3}\frac{m^3}{d^3} \quad (9)$$

$NH = f$ (versine of circle, radius R, for a chord $GT = 2d$).

$$IH = \frac{LG}{2} = \frac{K}{6}\frac{(m+d)^3}{d^3}$$

whence

$$f_p = \frac{K}{3}\frac{m^3}{d^3} + f - \frac{K}{6}\frac{(m+d)^3}{d^3}$$

$$= f - \frac{K}{6}\left[\left(1+\frac{m}{d}\right)^3 - 2\left(\frac{m}{d}\right)^3\right]$$

$$= f - \frac{K}{6}[(1+M)^3 - 2M^3] \quad (10)$$

if $M = \frac{m}{d}$ denotes the distance PQ as a multiple of the interval d.

The versine f_T at peg T is equal to TU = TV — VU (fig. 31), TV = f, VU = $\frac{PN}{2} = \frac{K}{6}\frac{m^3}{d^3}$.

From which $f_T = f - \frac{K}{6}\frac{m^3}{d^3} = f - \frac{K}{6} M^3$ (11)

on making $\frac{m}{d} = M$.

The difference K between two succes-

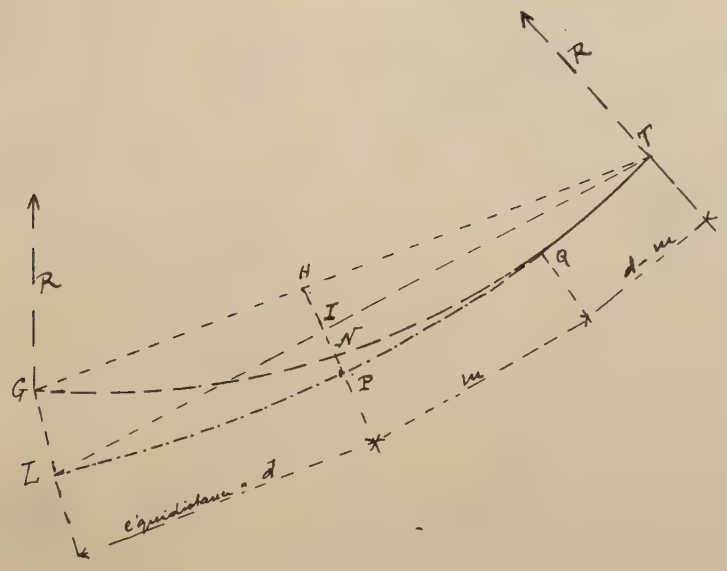


Fig. 30.

sive versines is equal to the value of versine f divided by the number of intervals over which the parabolic transition extends.

Knowing f, K and the particular versines f_o, f_B, f_P, f_T, it is easy to construct the diagram of versines for the theoretical parabolic transition.

If the following substitutions are made in equations (7), (8), (10), (11), taking K = 12 mm., and d = 10 m., with

N = 0.2	N = 0.8
M = 0.8	M = 0.4

the versine diagrams of figures 32 and 33 are obtained.

According to what has been previously stated, the curvature diagram is the straight line AQ_1, when the scale for curvature is suitably chosen.

Conversely a versine diagram similar to the latter, the values of the versines f_o, f_B, f_P, f_T, of K and of d verifying equations (7), (8), (10), (11), repre-

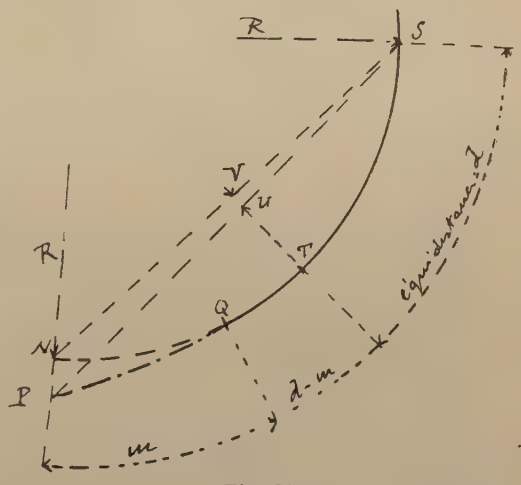


Fig. 31.

sents a parabolic transition tangential at A to the straight line and at Q to the circle whose versine is f, and such that point A is n metres distant from point B and point Q is m metres from point P, if the curvature diagram is the straight line AQ_1.

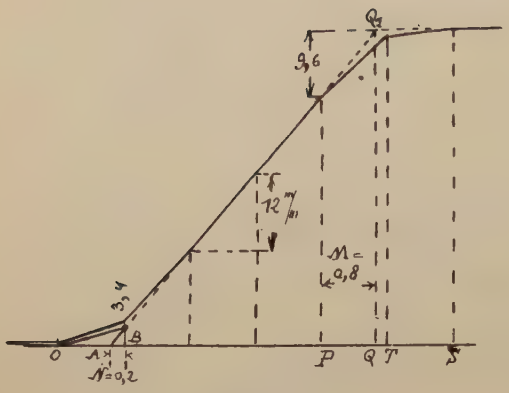


Fig. 32.

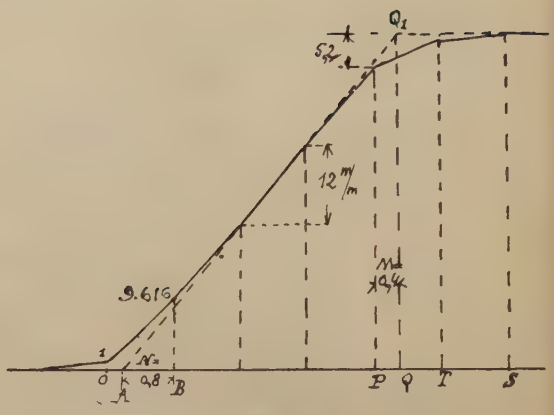


Fig. 33.

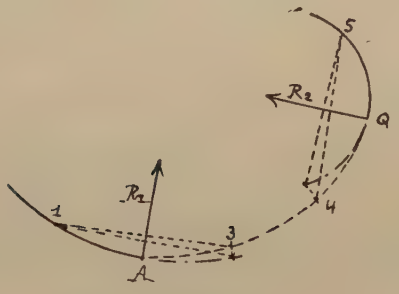


Fig. 34.

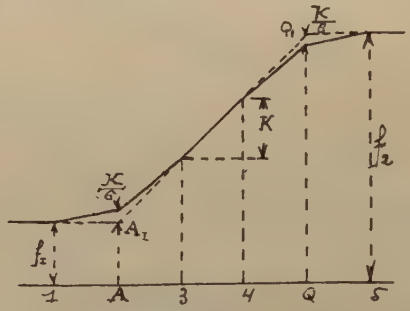


Fig. 35.

e) *Diagram of versines and curvatures for two circular arcs of different radius, joined by a parabolic transition.*

1. *When the tangent points of the circles with the transition each coincide with a peg* (fig. 34).

On applying equation (9) it is easily found that the versine diagram is that shewn in figure 35, the straight line A_1Q_1 being, to a suitable scale, the curvature diagram.

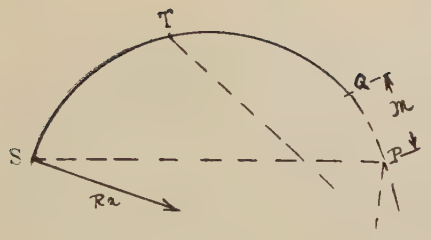
2. *When the tangent points of the circles with the transition do not coincide with a peg.*

Let AX be the circle of radius R_1 and QS the circle of radius R_2 joined together by the parabolic transition A..... Q. (fig. 36), and let A be the tangent point of the circle, radius R_1, with the transition, A being situated at n metres from peg B; also let Q be the tangent point of the circle, radius R_2, with the transition, being situated at m metres from peg P, it is easily seen that

$$f_o = f_1 + \frac{K}{6} N^3 \qquad (12)$$

(f_1 = versine of circular arc whose radius is R for a chord equal to 2 d).

$$f_B = f_1 + \frac{K}{6} [(1 + N)^3 - 2N^3] \qquad (13)$$



(f_2, versine of the circular arc of radius R_2, for a chord equal to 2 d).

Equations (14) and (15) are identical with equations (10) and (11).

For K = 12 mm., N = 0.20, M = 0.8,

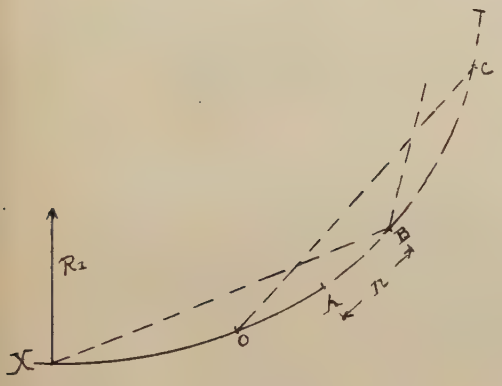


Fig. 36.

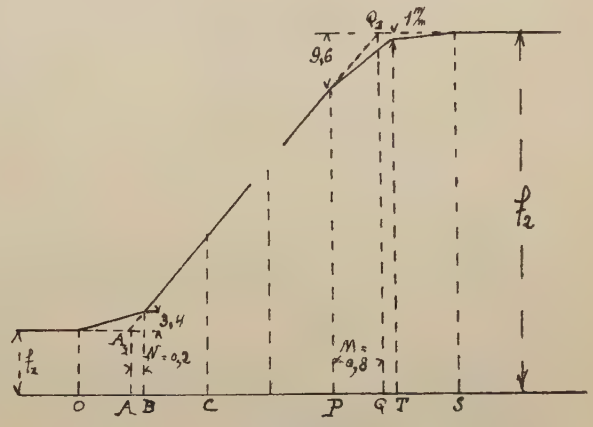


Fig. 37.

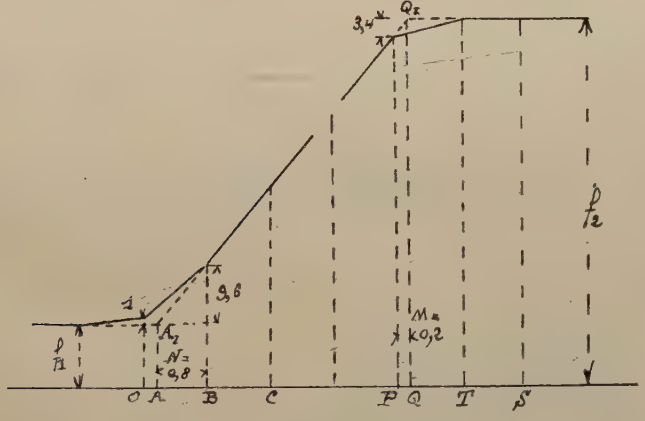


Fig. 38.

On making $f_1 = 0$, equations (7) and (8) result.

$$f_D = f_2 - \frac{K}{6}[(1+M)^3 - 2M^3] \quad (14)$$

$$f_T = f_2 - \frac{K}{6} \times M^3 \quad (15)$$

the versine diagrams of figure 37 is obtained.

For N = 0.8, and M = 0.2, the versine diagram is that of figure 38, the straight line A_1Q_1 being, to a suitable scale, the curvature diagram.

Conversely, a versine diagram similar to the latter, the value, of f_o, f_B, f_P, f_T, of K and of d verifying formulas (12), (13), (14), (15) represents a parabolic transition joining two circles of radii R_1 and R_2 respectively, being tangential to

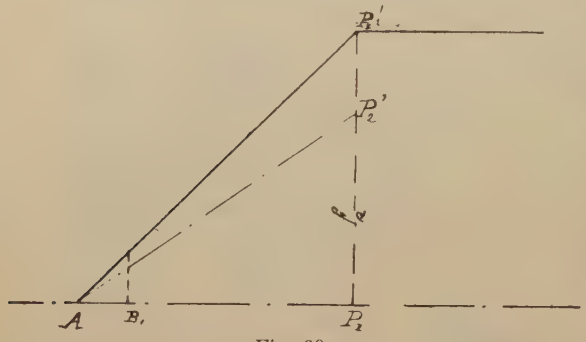


Fig. 39.

the first circle at A and to the second circle at Q, and such that point A is situated at n metres from peg B, and point Q at m metres from peg P, if the curvature diagram is the straight line A_1Q_1

Note. — The diagrams of figures 28, 32, 33, 35, 37, 38 show inflections which do not constitute irregularities as might be imagined at first sight.

These versine diagrams are those of correct alignments, whose progressive curvatures are represented by the straight lines OB, AQ_1, or A_1Q_1, if the scale is suitably chosen.

Instead of improving them, it is often necessary to effect them at one of the extremities of the curve because it is very seldom that the tangent points of parabolic transitions in a curve each coincide with one of the pegs at intervals of 10 m. (32 ft. 9 3/4 in.).

Parabolic transitions or incorrect spirals.

a) *Characteristics of the curve having for its versine and curvature diagram a straight line inclined to the abscissæ axis.*

Assuming the straight line AP'_1 (fig. 39) to be the versine and curvature diagram (if the curvature scale is suitably chosen) of a curve having progressive curvatures, what are the characteristics of this curve ?

It is noticed that $f_A = o$, $f_{P_1} = f_R$, whilst the versine diagram for a theoretical parabolic transition would give

$$f_A = \frac{K}{6}, \quad f_{P_1} = f_R - \frac{K}{6}.$$

In order to understand the nature of the contact of this curve with the straight line and with the circular arc of radius R, let the transition ABP (fig. 40) be drawn tangential to the straight line and to the circular arc, of radius R, at A and P respectively.

The versine at point A is equal to $\frac{K}{6}$, in order to reduce it to nothing it is sufficient to rotate the transition about point A so that point B comes to B_1 on the straight line XX'. The transition has taken up the position AB_1P_1. At peg P the versine is equal to $f_R - \frac{K}{6}$; in order that it may become equal to f_R, let the circular arc rotate about peg P_1 so that $DE = \frac{K}{6}$ and then

$$f_{P_1} = f_R - \frac{K}{6} + \frac{K}{6} = f_R.$$

Point C_1 has come to F so that

$$FC_1 = 2\frac{K}{6} = \frac{K}{3}.$$

Finally the versine diagram for the transition thus modified, measured between pegs P_1 and A is a straight line P'_1 A, inclined to the abscissæ axis (fig. 39).

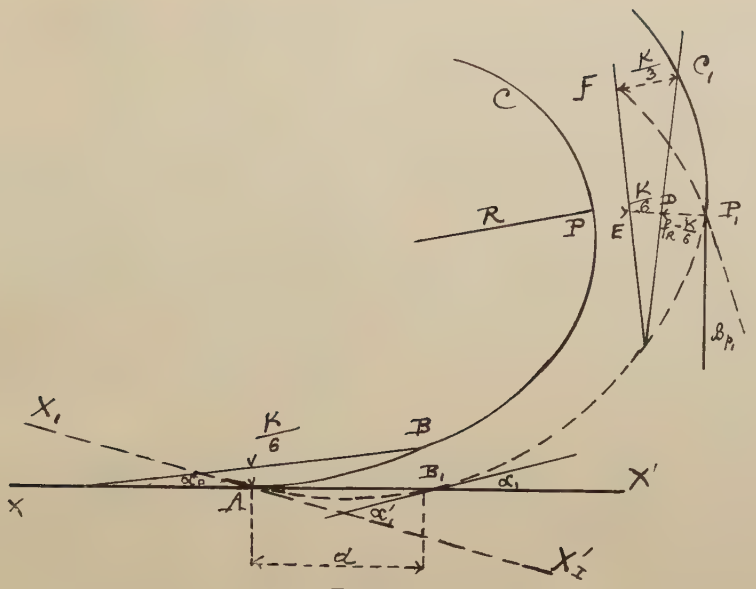


Fig. 40.

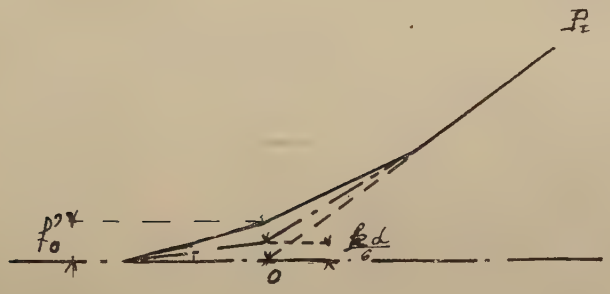


Fig. 41.

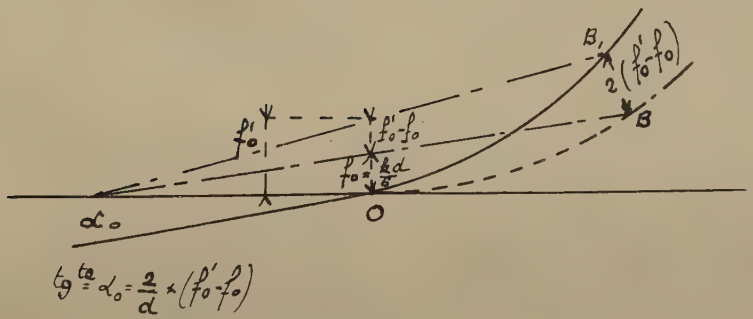


Fig. 42.

Conversely, if the arc AB_1 (fig. 40) be neglected, which in practice is confused with the straight XX', the straight line AP'_1 represents an arc of transition B_1P_1 cutting the straight alignment at B_1 at an angle α_1 (fig. 40), and cutting the circle which it meets in P_1 at an angle βp_1.

Evidently this interpretation is exact only when the curvature diagram is the straight line AP'_1 (the scale of curvatures being suitably chosen) or a straight line such as AP'_2, the scale of curvatures being anything (1).

At B_1, the radius of curvature is equal to $\frac{d}{2k}$ (2), and at P_1 it is equal to R.

If the versine diagram extends over n intervals, the length of the arc of the transition is equal to $(n - 1)$ intervals.

Calculating α_1,

$\alpha_1 = \alpha'_1 - \alpha_o$ (fig. 40).

$$\tan \alpha_o = \frac{BB_1}{d}.$$

The equation to the transition, as a function of K, the difference between two successive versines, is $Y = \frac{Kx^3}{3d^3}$.

(1) This versine diagram may also represent a curve composed of circular arcs of radius R_1, R_2, R_3, etc., tangential to one another and to the straight line and whose versines are in *arithmetical progression*. But then the curvature diagram is no longer the line AP'_1, it is formed of lines parallel to the abscissæ axis, of lengths equal to those of the circular arcs and drawn at distances $\frac{1}{R_1}$, $\frac{1}{R_2}$, $\frac{1}{R_3}$, etc., and the superelevation can no longer be conveniently attained because it would be necessary to have a series of steps.

(2) Actually

$$y = \frac{kx^3}{3d^2}, \quad y' = \frac{kx^2}{d^2}, \quad y'' = \frac{2kx}{d^2};$$

for $x = d$, $y'' = \frac{2k}{d} = \frac{1}{R}$ and $R = \frac{d}{2k}$.

For $x = d$, $Y = BB_1 = \frac{K}{3}$

and $\tan \alpha_o = \frac{K}{3d}$.

For calculating α'_1, we note that the displaced transition AB_1P_1 is tangential at A to a straight line $X_1X'_1$ which cuts the straight line XX' at an angle α_o.

In consequence, the ordinates of this transition ought to be referred to the straight line $X_1X'_1$ and $\alpha'_1 = \tan^{-1} \frac{dy}{dx}$ at point B_1 whose abscissa is equal to d.

From

$$Y = \frac{Kx^3}{3d^3},$$

is obtained

$$\frac{dy}{dx} = \frac{Kx^2}{d^3}$$

and when $x = d$:

$$\frac{dy}{dx} = \frac{K}{d}$$

and $$\alpha'_1 = \tan^{-1} \frac{K}{d},$$

whence

$$\alpha_1 = \tan^{-1} \frac{K}{d} - \tan^{-1} \frac{K}{3d}.$$

On replacing the angles by their tangents, the angles being very small

$$\alpha_1 = \frac{K}{d} - \frac{K}{3d} = \frac{2K}{3d}.$$

Let us calculate β_{p_1}.

It has been seen that $FC_1 = \frac{K}{3}$ (fig. 40),

hence $\tan \beta_{p_1} = \frac{K}{3d}$.

For a circular arc of 500 metres radius and a transition of 80 metres length,

$$k = \frac{0.10}{80} = 0.00125;$$

angles α_1 and β_1 are very small and may be neglected.

On rotating the transition about O, in such a manner that point B (fig. 42) withdraws from the straight line, versine f_o becomes greater than $\frac{kd}{6}$ and the versine diagram for the transition in the neighbourhood of the origin O is that of figure 41.

If f'_o is the new versine at O, the transition then makes with the straight an angle α_o whose tangent is equal to

$$\frac{2}{d}\left(f'_o - f_o\right) = \frac{2}{d}\left(f'_o - \frac{kd}{6}\right) = \frac{2}{d}\left(f'_o - \frac{K}{6}\right)$$

(fig. 42).

It is seen likewise that when the versine f'_p at peg P is greater than f_R, the circular arc and the transition intersect in P at an angle β_p whose tangent is equal to

$$\frac{2}{d}(f'_p - f_R)$$

and when the versine f'_p at peg P is smaller than $f_p = f_R - \frac{K}{6}$, the circular arc and the transition make a re-entering angle at this peg whose tangent is equal to

$$\frac{2}{d}(f_p - f'_p).$$

For the two last cases, the versine diagrams in the neighbourhood of peg P are those shown in figures 43 and 44.

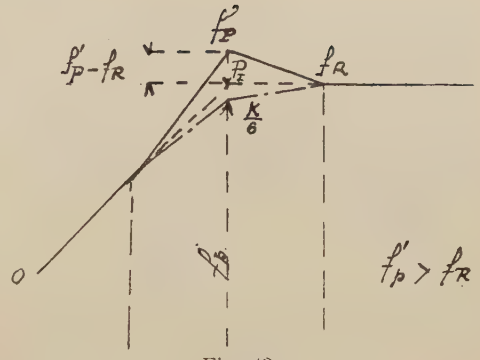


Fig. 43.

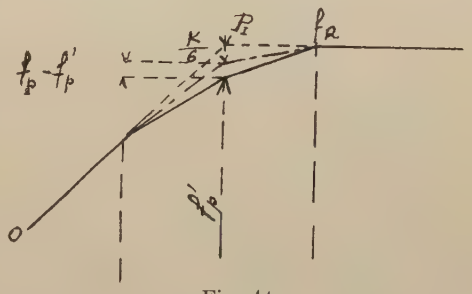


Fig. 44.

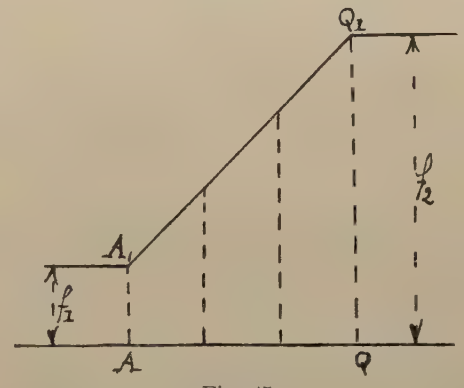


Fig. 45.

Note. — From an inspection of figures 34 and 35 it is similarly seen that the straight line A_1Q_1 (fig. 45) is the versine diagram for an arc of a parabolic transition making at A, with the circle of radius R_1, and at Q, with the circle of radius R_2, angles whose tangents are equal to $\frac{K}{3d}$, on condition that the line A_1Q_1

should be the curvature diagram (the scale of curvatures being suitably chosen).

At A the radius of curvature is equal to R_1, at Q it is equal to R_2. If the versine diagram extends over n intervals, the arc of the transition has a length of n intervals.

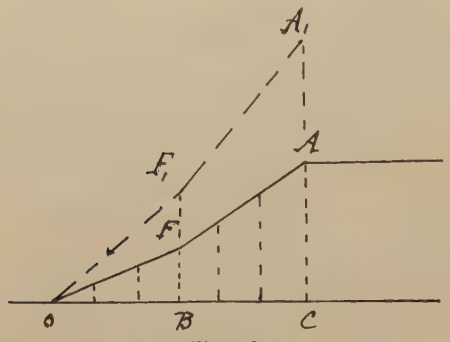


Fig. 46.

This versine diagram may also represent a curve composed of circular arcs of radii R_3, R_4, R_5, etc., tangential to one another and to circles of radii R_1, R_2 [see foot note (1) on page 2028].

b) *Characteristics of the curve having as versine and curvature diagram a broken line OFA inclined to the abscissæ axis* (fig. 46).

Let a part of the diagram extending over two intervals and composed of two MF and FN, cutting at F, be considered.

The slope of MF is k_1, that of FN is k_2 (fig. 47).

MF is the diagram of a section of a parabolic transition whose versines would be given by the equation $f_x = k_1 x$; FN is the diagram of a section of a transition, different from the preceding one, whose versines would be given by the equation $f_x = k_2 x$.

These two transitions meet a peg B since they have the same versine BF at this point.

Let the circular arc DBE be drawn, of length equal to 2 d, and having BF for its versine (fig. 48).

Let $AD = EH = \frac{k_1 d}{3}$.

The arc ABH is an arc of a transition tangential at B to the circular arc DBE; its versine diagram is the straight line MFP (fig. 47).

Let $EC = DK = \frac{k_2 d}{3}$; the arc CBK is an arc of a transition tangential at B to the circular arc DBE, its versine diagram is the straight line QFN (fig. 47).

Considering the alignment ABC, and taking chord AB, versine BG at B is greater than BF.

In order to make BG equal to BF, it is necessary to rotate arc BC about point B in such a manner that point C comes to H and that chords AH and AC coincide. Point C then describes a circular arc equal to

$$CH = EC - EH = \frac{k_2 d}{3} - \frac{k_1 d}{3} = d\left(\frac{k_2 - k_1}{3}\right)$$

and the arcs of the transitions AB and BC intersect at B making an acute angle whose tangent is equal to

$$d\left(\frac{k_2 - k_1}{3d}\right) = \frac{k_2 - k_1}{3} = \frac{K_2 - K_1}{3d}. \ (1)$$

It should be observed that angle MFN (fig. 47) is convex towards the abscissæ axis; if it were concave, that is to say if k_2 were less than k_1, the angle of intersection at B of the transition arcs AB

(1) When the two parabolic transition arcs OB and BC are tangential at B, the versine at this peg is equal to

$$BF + FG = BF + \frac{K_2 - K_1}{6}.$$

and BC would be projecting instead of re-entering.

The curvature diagram being the broken line OFA (the scale of curvatures being suitably chosen) the versine diagram of figure 46 corresponds therefore to a curve formed by two sections or arcs of different transitions which intersect at peg B forming a re-entering angle whose tangent is equal to

$$\frac{K_2 - K_1}{3d}.$$

Moreover, at peg O, the versine f_o being zero, the first arc of transition cuts the straight line at an angle whose tangent is equal to $\frac{2K_1}{3d}$.

At peg C, the second transition cuts the curve of radius R at an angle whose tangent is equal to $\frac{K_2}{3d}$.

c) *Characteristics of parabolic transitions defined by the versine diagrams of figures 49 and 50.*

Let the transition of figure 29 and its versine diagram figure 33 now be considered.

In order that the diagram of figure 33, from peg O to point B, should become similar to the diagram of figure 49, it is necessary that the versine f_o should be zero and that the versine at peg B should be equal to $K \times N \left(N = \frac{n}{d}\right)$.

These results can only be obtained by rotating the arc of the transition AC (fig. 29) about A, in such a manner that point B comes to E on XX′ (fig. 31), point C to C_1, which has the effect of reducing f_o to zero; then to rotate the part EC_1 of the transition about E so

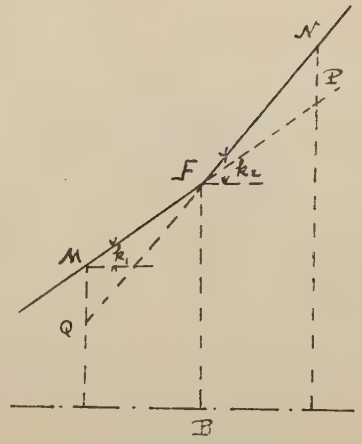


Fig. 47.

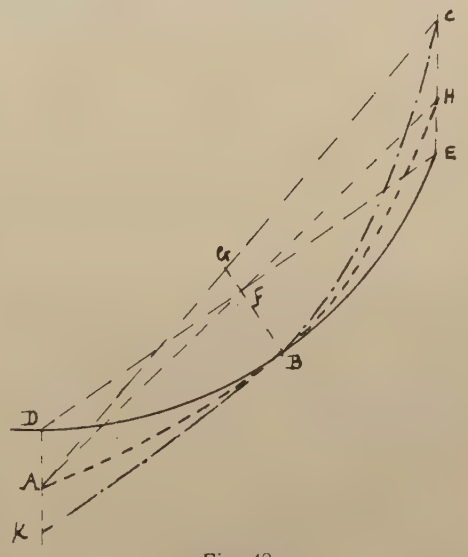


Fig. 48.

that the versine EG becomes equal to $K \times N$.

Stated briefly, the diagram of figure 49 represents an arc of the transition cutting the straight line at peg E at an angle α_1 whose tangent is $\frac{2k}{3}\left(\frac{n}{d}\right)^2$ (a similar calculation to that on page 2028),

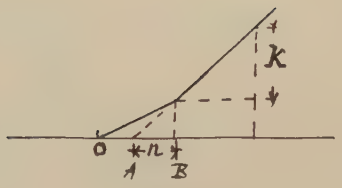


Fig. 49.

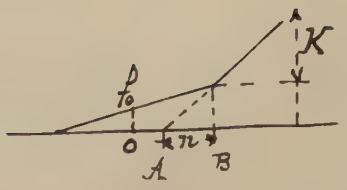


Fig. 50.

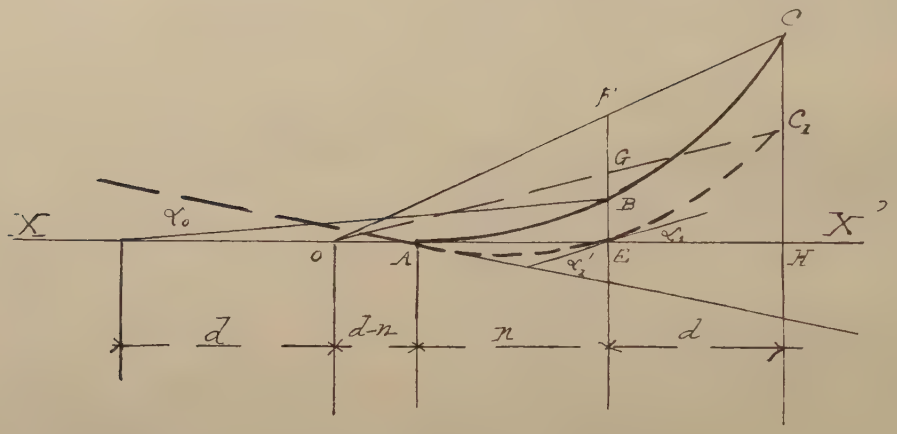


Fig. 51.

increased or diminished by the angle $\frac{2}{d}(K \times N - EG)$ measuring the rotation imposed on arc EC_1 in order that EG becomes equal to $K \times N$.

Calculating EG,

$$EG = \frac{C_1H}{2} = \frac{CH - CC_1}{2}$$

$$CH = \frac{K}{3}\left(\frac{n+d}{d}\right)^3,$$

$$CC_1 = \frac{BE}{n}(n+d) = \frac{k}{3}\left(\frac{n}{d}\right)^2 (n+d).$$

If the rotation of arc AC about A is such that versine f_o diminishes without becoming zero, or increases, and that the rotation of BC about B gives a versine at this point equal to $K \times N$, the diagram of figure 49 is obtained.

d) *Characteristics of parabolic transitions as defined by figure 52.*

Let the transition LPQ (fig. 30) and its versine diagram (fig. 33) be considered.

In order that the diagram of figure 33, from peg P to peg T, may become similar to the diagram of figure 52, it is necessary that the versine at peg P should become equal to $AP \times \frac{K}{d}$ (fig. 33) and that the versine at peg T should become equal to the versine f_R of the circular arc of radius R.

Considering figure 53, and producing the transition arc LPQ to R, it will meet the circular arc tangentially at Q.

Taking chord RL, the versine PM of

the transition at peg P is evidently equal to

$$AP \times \frac{K}{d}.$$

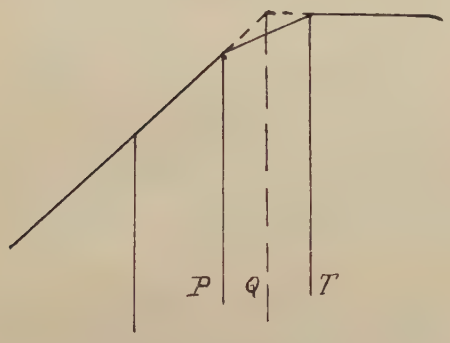


Fig. 52.

Also :

$$RT = \frac{K}{3}\left(\frac{d-m}{d}\right)^3,$$

$$MI\ \frac{RT}{2} = \frac{K}{6}\left(\frac{d-m}{d}\right)^3.$$

Making the transition arc LP turn about P. to the position L_1P, so that $LL_1 = 2\,MI = RT = \frac{K}{3}\left(\frac{d-m}{d}\right)^3$, and taking chord L_1T, it will pass through point M, the versine at point P is still $PM = AP \times \frac{K}{d}$ and, at P, the transition arc makes an angle whose tangent is equal to

$$\frac{K}{3d}\left(\frac{d-m}{d}\right)^3 = \frac{k}{3}\left(\frac{d-m}{d}\right)^3, \qquad k = \frac{K}{d}.$$

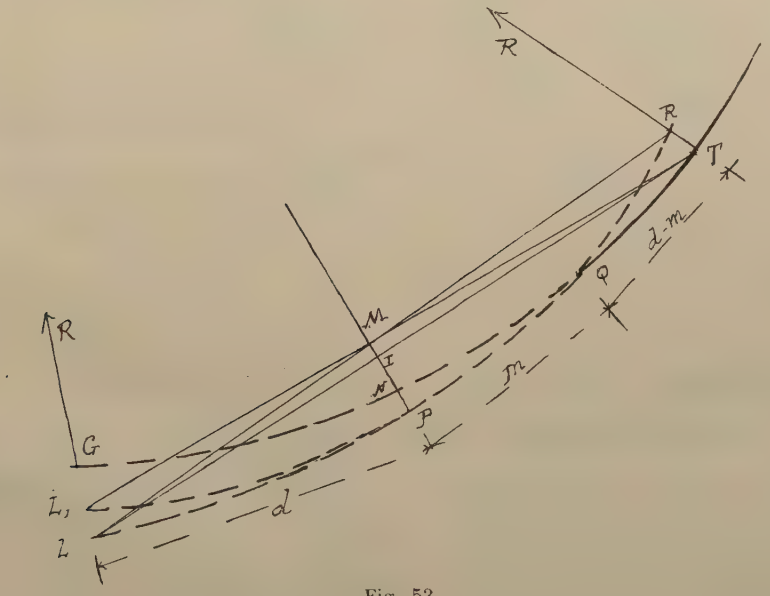


Fig. 53.

Considering now figure 31, in order that the versine TU at point T may become equal to versine f_R of the circular arc, it is sufficient to rotate the circular arc TSY about T (fig. 54) into position TS_1Y_1 in order that $S_1S = PN = \frac{K}{3}\left(\frac{m}{d}\right)^3$.

Taking the chord S_1P, the versine at T

is equal to TV, that of the tangential circle of radius R.

The circular arc of radius R makes at T an angle whose tangent is equal to :

$$\frac{K}{3d}\left(\frac{m}{d}\right)^3 = \frac{k}{3}\left(\frac{m}{d}\right)^3.$$

Finally the versine diagram of figure 52 indicates that the transition is broken at

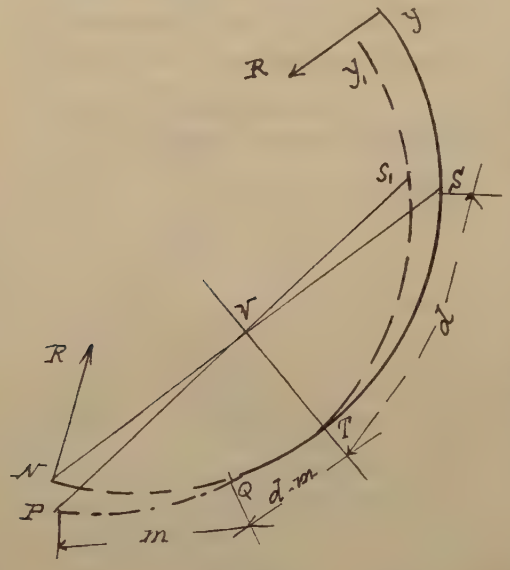


Fig. 54.

P following an angle whose tangent is $\frac{k}{3}\left(\frac{d-m}{d}\right)^3$ and that the tangential circle of radius R is broken at T following an angle whose tangent is equal to $\frac{k}{3}\left(\frac{m}{d}\right)^3$.

General rule. — The numerous examples which have been dealt with show that in order to determine the geometrical characteristics of a given alignment whose versine diagram is known, it is enough to compare the latter with versine diagrams having alignments of regular geometrical outline, then to study the rotation of these correct alignments as has been done, in order to obtain a versine diagram identical with that of the alignment whose geometrical characteristics are sought.

Versine diagrams which it is preferable to adopt.

The work which may have to be done with versine diagrams is greatly facilitated when these refer to correct alignments.

It is, therefore, preferable when adjusting a distorted curve, if it is desired to avoid big slues, to reconstruct it with correct parabolic transitions and circular arcs of different radii and tangents between them.

It will be seen a little later what are maximum differences that can be allowed between the radii of two consecutive circular arcs.

The following versine diagrams may then be adopted.

a) *Circular arcs.*

When the tangent point coincides with one of the pegs equidistant by 10 m. (32 ft. 9 3/4 in.):

Versine diagrams of figures 2 and 14.

When the tangent point does not coincide with one of the pegs equidistant by 10 m.:

Versine diagrams of figures 9 to 12 and figures 16 and 17.

Versine diagrams of circular arcs which cut straight lines (fig. 5) or which cut one another (fig. 19) ought not strictly speaking to be adopted except when the angles of intersection are very small.

b) *Parabolic transitions.*

When the tangent points each coincide with one of the pegs equidistant by 10 m.:

Versine diagrams of figures 28 and 35.

In the contrary case :

Versine diagrams of figures 32, 33, 37 and 38.

Versine diagrams representing transitions cutting straights or circular arcs with which they join, figures 39, 41, 45, 46, 49, 50, which should only be adopted in exceptional circumstances unless the angles of intersection are very small.

CHAPTER II.

Superelevation diagrams.

In principle, at every point of a curve there should be provided a superelevation $S = \frac{C}{R} = C \times \frac{1}{R}$ proportional to the curvature $\frac{1}{R}$ at the given point (1).

A knowledge of the curvature diagram leads to that of the superelevation diagram. The latter may be taken for the former when a certain scale is selected.

The different versine and curvature diagrams dealt with in the preceding chapter will now be reviewed.

Circular arcs.

a) *Superelevation diagram of a circular arc joining directly with adjacent straights.*

The curvature at each point of a circle of radius R being constant and equal to $\frac{1}{R}$, the superelevation diagram is a straight line BC, drawn parallel to the abscissæ axis, at a distance $\frac{C}{R}$, between the ordinates corresponding to the ends of the circular arc (fig. 55).

In the straights a ramp of superelevation has to be provided and the diagram is thus the trapezium ABCD. The ramps are drawn according to permitted inclinations.

Instructions issued by railway companies usually prescribe, at each point of tangency of circle and straight, only half the superelevation $\frac{C}{R}$; in this case the superelevation diagram is the trapezium EFGH.

Mr. Marié (1) advises, on account of the oscillation of the springs of vehicles, that at the tangent point on entering the curve, a superelevation slightly greater than half the theoretical value should be provided, and that at the tangent point on leaving the curve a superelevation slightly less than half the theoretical value should be provided (2).

The diagrams of superelevation which have just been established evidently agree with the diagrams of versines of figures 2, 4, 5, 6, 7, 9, 10, 11, 12, the latter being those of a circular arc meeting a straight line tangentially or cutting it at an angle small enough to be negligible.

---

(1) In comparing this equation with that which gives the superelevation $S = \frac{1.5\,v^2}{gR}$, it is noticed that $C = \frac{1.5\,v^2}{g}$, (v is the speed in metres per second).

(1) « Les oscillations du matériel des chemins de fer à l'entrée en courbe et à la sortie » (Oscillation of stock on railways at the start and finish of curves). (*Proceedings* of the Société des Ingénieurs Civils [France] of November 1905).

(2) The theoretical superelevation is given by the equation $S = \frac{1.5\,V^2}{gR}$ (V is the speed in metres per second).

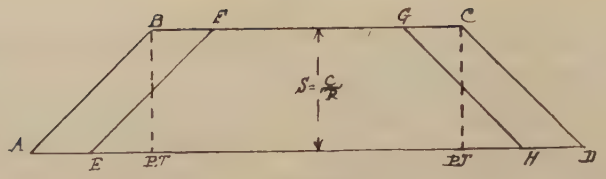


Fig. 55.

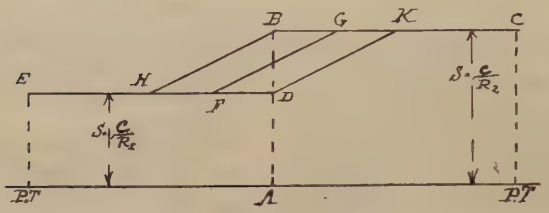


Fig. 56.

b) *Superelevation diagram for two circular arcs of radii* R_1 *and* R_2 *respectively, being mutually tangential or cutting one another at angles small enough to be negligible* (figs. 13, 15, 18, 21).

According to what has been said above, the superelevation diagram is composed of two straights BC, ED (fig. 56) parallel to the abscissæ axis, and drawn respectively at distances $\frac{C}{R_1}$, and $\frac{C}{R_2}$ between the ordinates corresponding to the ends of the circular arcs.

As it is impossible to provide two different superelevations at A, the point of tangency or of contact of the two circular arcs, one of the ramps HB, FG or DK is introduced between the parallels BC and ED.

The ramps at the ends of the circular arcs towards the straights are placed as indicated in the preceding paragraph.

This superelevation diagram with its different ramps clearly agrees with the versine diagrams of figures 14, 16, 17, 19, 20, 22, these diagrams being those of two circular arcs mutually tangential or cutting at angles small enough to be negligible.

Notes. — Superelevations are not necessarily proportional to versines whilst they are always so to the curvature $\frac{1}{R}$.

In order to draw the superelevation diagrams, a start is made by determining from the versine diagram, as has been pointed out in the previous chapter, the points of tangency or of contact either of the circular arcs with the adjacent straights or of the circular arcs with one another.

c) *Superelevation diagram for curves of contrary flexure.*

When the circular arcs are consecutive without the interposition of a straight, it is evident that the normal superelevation is obtained entirely on the curves, which have not over part of their length the superelevation corresponding to their radius. This alignment is suitable only for low speeds; 30 to 40 km. (18.6 to 25 miles) per hour, unless the curves are of very great radius. For high speeds,

from about 60 km. (37 miles) per hour it is necessary to separate curves of contrary flexure by a straight of sufficient length to enable the ramps to be inserted either wholly or partially therein.

The instructions of some railway companies even require that a straight of at least 10 m. (32 ft. 9 3/4 in.) in length and having both rails at the same level should be left between transitions. The superelevation diagram is then that of figure 57.

In the opinion of the author, this straight is a defect rather than an improvement.

The lateral movement will be considered of a vehicle (assumed to consist of a body suspended on an axle) when the in-

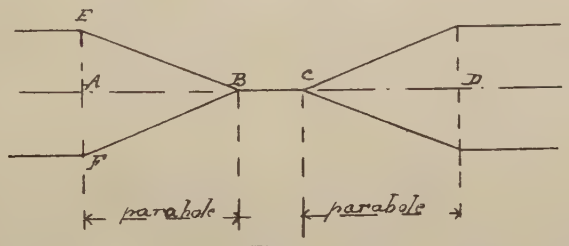


Fig. 57.

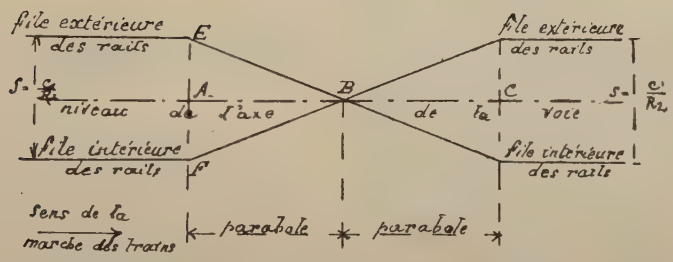


Fig. 58.

Explanation of French terms in figures 57 and 58: File intérieure des rails = Inner rail. — File extérieure des rails = Outer rail. — Niveau de l'axe de la voie = Level of the centre line of the track. — Parabole = Parabola. — Sens de la marche des trains = Direction of travel of trains.

termediate straight does not exist (fig. 58).

Being given the direction of travel, the wheel which moves on the outer rail of the track forming parabola AB drops from E to B (fig. 58) and that which runs on the inner rail rises from F to B; the axle therefore rotates laterally in a clockwise direction in a vertical plane.

In the parabola BC, the axle has the same sense of lateral rotation and when the amount of variation in superelevation is the same in both parabolas, the velocity of lateral rotation is the same.

The suspended body of the carriage, following the axle in its movement, has therefore also a continuous movement of lateral rotation from A to C, without oscillation, when the parabolas of contrary flexure follow one another without the interposition of a straight.

If the straight alignment BC (fig. 57) be interposed between the two parabolas, the axle, arriving at B on two level rails,

stops its lateral rotation whilst the suspended body of the carriage, by virtue of its inertia, continues to rotate and oscillate transversely, the springs being alternately compressed and released.

At C the same cause of oscillation is present.

The straight alignment BC interrupts at B and at C the continuous rotative movement of the vehicle.

If, on the other hand, it is noted that for a vehicle with several axles, the maximum value of the compression and decompression of the springs does not exceed that resulting from the variation of superelevation, that all the axles have an equal speed of lateral rotation, that the entry of the vehicle into the region of the point of inflection takes place without difficulty (1), it is therefore better not to interpose a straight alignment between the parabolas and to utilise the entire distance between the tangent points of the curves for the accommodation of parabolic transitions as long as possible, and corresponding superelevation ramps.

Nevertheless, high speed travel will not be satisfactory unless the superelevations correspond closely to the speed.

When the curves of contrary flexure are, for example, continuations of turnouts, which cannot be provided with transitions, it is possible to give, as Mr. Marié advises, a little less than half the theoretical superelevation at the tangent point at the exit from the first curve and a little more than this half at the tangent point at the entrance to the following curve.

The variations of superelevation are effected entirely on the straight AB lying between the two tangent points A and B of the curves.

It is preferable, as stated above, not to interpose between the superelevation ramps, a portion of non-canted road, but to use the whole of the straight AB for the provision of ramps, in order to have the variation in superelevation as small as possible.

Parabolic transitions or theoretical spirals.

a) *Superelevation diagram for a transition or theoretical spiral.*

1. *When the points where the transition is tangential to the straight and to the circular arc each coincide with a peg.*

The straight OB (fig. 28), being the diagram of curvatures of a transition or theoretical spiral, is also the superelevation diagram when the scale of the latter is $\frac{C}{50}$ times smaller than the versine scale, C being the superelevation coefficient.

In fact :

$$S = C \times \frac{1}{R}, \qquad f = \frac{d^2}{2} \times \frac{1}{R}$$

from which

$$\frac{S}{f} = \frac{2C}{d^2} = \frac{C}{50} \text{ for } d = 10 \text{ m.}$$

(1) At 10 m. (32 ft. 9 3/4 in.) from the origin of a parabolic transition the ordinates y usually measure only a few millimetres, the versine $f_o = \frac{Y}{2} = \frac{K}{6}$ is very small and negligible (figs. 24, 28). Consequently (fig. 23) if the ordinates AF and CE are very small, arcs AT and TC (which are supposed to be transition arcs) are in practice capable of confusion with TF and TE, parts of the straight. It is possible to say, therefore, without appreciable error, that the origins of two adjacent parabolic transitions are separated by a straight line 20 m. (65 ft. 7 3/8 in.) long.

When the superelevation scale is anything, the diagram is a straight line inclined to the abscissæ axis having its origin at C and its extremity on the pth ordinate.

2. *When the points where the transition is tangential to the straight and to the circular arc do not each coincide with a peg.*

By the same argument as that above, it is seen that the superelevation diagram is, either the straight line AQ_1 (figs. 32 and 33) when the superelevation scale is $\frac{C}{50}$ times smaller than the versine scale, or a straight line having its origin at A and its extremity on the ordinate through Q when the superelevation scale is anything.

b) *Diagram of superelevation for two circular arcs of different radius joined by a theoretical transition.*

1. *When the point where the circles and transition are tangential each coincide with a peg.*

The superelevation diagram is either the straight line A_1Q_1 (fig. 35) or a straight line having its origin at A_1 and its extremity on the ordinate passing through Q.

2. *When the points where the circles and transition are tangential do not each coincide with a peg.*

The superelevation diagram is either the straight line A_1Q_1 (figs. 37 and 38) or a straight line having its origin at A and its extremity on the ordinate passing through Q.

Parabolic transitions or incorrect spirals.

a) *Superelevation diagram for the transition whose versine and curvature diagram is a straight line AP'_1 inclined to the abscissæ axis* (fig. 39).

The superelevation diagram is either a straight line AP'_1, if its scale is $\frac{C}{50}$ times smaller than the versine scale or a straight line having its origin at A and its extremity on the pth ordinate when the superelevation scale is anything.

The same thing applies for the versine diagrams of figures 41, 43, 44, for which the curvature diagram is always the line AP'_1.

b) *Superelevation diagram for a transition joining two circular arcs of radius R_1 and R_2, and whose versine and curvature diagram is the straight line A_1Q_1* (fig. 45).

The superelevation diagram is either the straight line A_1Q_1, or a straight line inclined in the same direction to the abscissæ axis, having its origin at A_1 and its extremity on the ordinate passing through Q.

c) *Superelevation diagram for a transition whose versine and curvature diagram is a broken line inclined to the abscissæ axis.*

The superelevation diagram is either the broken line OFA (fig. 46), if the scale is suitably chosen, or a broken line such as OF_1A_1. In many cases this broken line is replaced by a straight line.

Calculation of superelevation in terms of the versine.

It is convenient to know the superelevation as a function of the versine :

$$f = \frac{d^2}{2R} = \frac{d^2}{2} \times \frac{1}{R},$$

d being the interval between pegs,

whence

$$\frac{1}{R} = \frac{2f}{d^2} \text{ and } S = C \times \frac{1}{R} = \frac{2C}{d^2} \times f.$$

CHAPTER III.

Examination of the simplifications to be used in the preparation of superelevation diagrams.

Superelevation diagram for a curve of varying radii.

Actually curves adjusted by the correction of versines are often constituted, between the transitions of entry and exit, of a series of small circular arcs of mutual tangency or cutting one another at negligible angles.

Should its relevant superelevation of $s = \frac{C}{R}$ be applied to each of these arcs ?

It is seen that this rule would necessitate setting the lines of rails of the curve to follow a sinuous longitudinal profile. The plane of the track would consist of an uneven succession of irregular surfaces on which vehicles would not travel without oscillating on their springs, which in certain cases would be prejudicial to the comfort of passengers.

Thus it is desirable to determine the maximum value which can be reached by the difference between versines of two successive circular arcs, in order that in providing the latter with the same superelevation, rapid speeds may be attained by the vehicles without appreciable shocks to passengers.

a) *Tangential circular arcs.*

The instructions of the big railway companies lay down that it is useless to interpose transitions between straights and curves of more than 2 000 m. (100 chains) radius.

They prescribe in addition the provision at the tangent point of a superelevation equal to half that which is reached in the body of the curve. The experience, which justifies these rules, shows that a curve of 2 500 m. (125 chains) radius may be entered without appreciable shock at a speed of 95 km. (59 miles) per hour ($v = 26$ m. (85 ft. 3 5/8 in.); a superelevation of

$$\frac{1}{2}\frac{75}{2\,500} = 0.015 \text{ (19/32 inch)}$$

being provided at the tangent point.

In this case the centrifugal force

$$\frac{mv^2}{R} = \frac{m \times \overline{26}^2}{2\,500}$$

is partly balanced by the component of the weight mg due to the superelevation.

This component is equal to :

$$\frac{mg \times 0.015}{1.50}$$

(1.50 m. [4 ft. 11 in.] = gauge of track).

Finally the force which would tend to throw a passenger, standing in a corridor of a coach, towards the outside of the curve, equal to

$$\frac{m \times \overline{26}^2}{2\,500} - \frac{mg \times 0.015}{1.50} \qquad (1)$$

is without effect on this passenger.

Let there be now considered two curves of radii R_1 and R_2, tangential to one another ($R_2 < R_1$) and having the same superelevation, namely, that which suits the curve of radius R_1.

The passenger referred to, whilst travelling from curve of radius R_1 to curve

of radius R_2 at a speed of 120 km. (75 miles) per hour (v = 33 m. [108 ft. 3 1/4 in.]) would be roughly subjected at the tangent point between the two curves to a force equal to the difference of the centrifugal forces.

$$\frac{mv^2}{R_2} - \frac{mv^2}{R_1} = mv^2\left(\frac{1}{R_2} - \frac{1}{R_1}\right) = m \times \overline{33}^2\left(\frac{1}{R_2} - \frac{1}{R_1}\right).$$

In order that this force may be without effect, it is sufficient that it should be equal to the value given by the equation (1), which gives

$$\frac{m\,\overline{26}^2}{2\,500} - \frac{mg \times 0.015}{1.50} = m\,33^2\left(\frac{1}{R^2} - \frac{1}{R_1}\right),$$

$$\frac{\overline{26}^2}{2\,500} - \frac{9.81 \times 0{,}015}{1.50} = \frac{\overline{33}^2}{\frac{d^2}{2}}\left(\frac{d^2}{2R^2} - \frac{d^2}{2R_1}\right) = \frac{\overline{33}^2 \times 2}{100}(f_2 - f_1),$$

(with d = 10 m. [32 ft. 9 3/4 in.]),

from which

$$f_2 - f_1 = \left(\frac{\overline{26}^2}{2500} - \frac{9.81 \times 0.015}{1.50}\right) \times \frac{100}{\overline{33}^2 \times 2} = 0.008 \text{ (5/16 inch).}$$

For a curve of radius 2 100 m. (105 chains) it is found that

$$(f_2 - f_1) = 0.009 \text{ (23/64 inch).}$$

On the other hand, the difference between the curvatures considered being very small and sensibly equal, whether passing from the straight to the curve of 2 500 m. (125 chains) radius or whether the curves whose versine difference is 9 mm. (23/64 inch) are considered, the lateral reactions which result from the rocking oscillations at the entrance to the curve are negligible. Consequently the same superelevation may be provided for two tangential circular arcs whose versines do not differ by more than about 10 mm. (25/64 inch).

b) *Intersecting circular arcs.*

When two circular arcs meet, without being tangential, the versine diagram being that of figure 19, it is known that they cut one another at an angle whose tangent is equal to $\frac{f_2 - f_1}{10 \text{ m.}}$ (10 m. being the interval between pegs).

In this case, there is a change of direction at point A (fig. 18) and a pendulum of length 1 m. and weight mg suspended in a coach which is travelling at a speed of v metres per second immediately has imparted to it a lateral velocity of

$$v_1 = v\frac{(f_2 - f_1)}{10}.$$

For v = 33 m. (108 ft. 3 1/4 in.), $f_2 - f_1$ = 10 mm. (25/64 inch), the calculation shows that the pendulum swings at 0.01.

This oscillation being negligible if follows that the lateral component of the velocity $\frac{33 \times 0.01}{10}$ is without effect on the said passenger.

Therefore, the same superelevation may be applied to two circular arcs which cut one another, when their versines do not differ by more than 10 mm. (25/64 inch).

JUNCTIONS.

In finding in a similar manner the versine differences $(f_2 - f_1)$ for speeds of 60, 70, 80, 90 and 100 km., there is found also, for a given speed, the value of the radii of the curves which may follow one another (without the necessity of varying the superelevation) in the alignments of junctions and of cramped portions of the track, where it is seldom possible to interpose transitions between the curves of different radii and consequently to make the superelevation vary in a progressive manner.

Nevertheless when it is possible to interpose a transition between two curves of different radii and to vary the superelevation, it is worth noticing that the diagram of figure 45 has the same shape as that of figure 14 (mutually tangential circular arcs) when the development AQ of the transition extends over two intervals, in practice the two alignments fit over one another.

There is indefiniteness which, to be removed, necessitates the interval being reduced along the whole length of the transition, that is to say more pegs should be placed. The author considers this to be unnecessary.

Actually, on account of the inertia of the supended body of the coach, during the short time which a train takes to travel over this transition, a passenger standing in the corridor is roughly subjected to the action of a difference of centrifugal force whether there is a transition of from 10 to 20 m. (32 ft. 9 3/4 in. to 65 fr. 7 3/8 in.) in length or whether the circular arcs are mutually tangential.

In order that the passenger's comfort should not be disturbed it is even preferable that the difference of versines $(f_2 - f_1)$ of two consecutive curves should not be more than 10 mm. (25/64 inch).

[313 : 625 .143.3]

Statistics of rail breakages during the year 1928.

In accordance with the resolution passed at the London Congress, 1925 (1), we publish the tables hereafter giving the information which has been sent in by the adherent administrations on the subject of the breakages of rails which occurred on their systems during the year 1928.

For the sake of simplification and unless stated otherwise :

Light rails applies to rails of a weight less than 85 lb. per yard (42.5 kgr. per metre).

Medium rails, to rails of 85 to 105 lb. per yard (42.5 to 52.5 kgr. per metre).

Heavy rails, to those weighing 106 lb. per yard (53 kgr. per metre) or over.

(1) See *Bulletin of the Railway Congress*, March 1926, p. 240.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Maximum axle load.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ARGENTINE.		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Buenos Ayres Great Southern Railway. (1)																
Light rails : (less than 85 lb. per yard).	...	...	...	...	...	...	...	...	...	...	...	...	44	1 125	24	12.8 to 16.7 depending on class of rail.
Medium rails : (85 and 105 lb. per yard).	6*	281	13	2	167	7.5	3	256	7.3	16	1 401	7.1	55	1 091	31	18.7
Total. . .	6	281	13	2	167	7.5	3	256	7.3	16	1 401	7.1	99	2 216	28	...

Number of thousands of English ton-miles : 677 373 027.
Total number of fractures : 126.
Number of fractures per 10 000 000 000 ton-kilometres or 6 115 682 800 English ton-miles : 114.

(1) See complemental table, p. 2045. — (*) Rails showed defects of manufacture.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Buenos Ayres and Pacific Railway.		Miles.						Miles.			Miles.			Miles.		English tons.
Light rails	...	...	...	...	...	...	1	716.3	0.54	17	716.3.	9.22	107	716.3	58.01	12.8 to 18.7
Medium rails	2	1 094.1	0.70	...	...	...	...	...	...	2	1 094.1	0.70	8	1 094.1	2.84	18.7
Total. . .	2	1 094.1	0.70	...	...	...	1	716.3	0.54	19	1 810.4	4.07	115	1 810.4	24.67	...

Number of train-miles : 9 760 942.
Total number of fractures : 137.
Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 87.212.

Buenos Ayres Great Southern Railway (*continued*).

Nature of fractures.	Light rails.		Medium rails.				
	5-20 years.	20 years.	5 years.	5-10 years.	10-15 years.	15-20 years.	20 years.
Complete fracture clear of fishplate	...	29	...	...	2	7	9
Complete fracture within fishplate span	...	14	3 (*)	2	...	7	2
Old cracks developed clear of fishplate	...	1	3 (*)	...	1	2	...
Old cracks developed within fishplate span	...	...	...	...	...	...	44
Total. . .	...	44	6 (*)	2	3	16	55

(*) Rails showed defects of manufacture.

NOTE.

Light rails comprise : 56 lb. per yard.	32 km.	(20 miles).
58 lb. — —	137 km.	(85 —).
65 lb. — —	9 km.	(6 —).
68 lb. — —	42 km.	(26 —).
70 lb. — —	304 km.	(189 —).
74 lb. — —	1 286 km.	(799 —).
Total . . .	1 810 km.	(1 125 miles.
Medium rails comprise : 85 lb. per yard.	3 298 km.	(2 049 miles).
100 lb. — —	1 844 km.	(1 146 —).
Total . . .	5 142 km.	(3 195 miles).

There is no track on this Railway, heavier than 100 lb. per yard.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Length of single track with each rail profile.	Age of rails : 5 years and less. Year of manufacture.	Number of fractures: In the length of the rail.	Number of fractures: At the joint.	Number of fractures: Total.	Length of single track of this class.	Number of fractures per 1 000 km or per 625 miles.	6 to 10 years. Year of manufacture.	Number of fractures: In the length of the rail.	Number of fractures: At the joint.	Number of fractures: Total.	Length of single track of this class.	Number of fractures per 1 000 km of per 625 miles
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Miles.					Miles.						Miles.	
BELGIUM.													
Belgian National Railway Company.													
Light rails :													
Weight : 38 kgr. (76.60 lb. per yard), profile adopted in 1863 (steel).	113.2	...	...	...	...	...	...	...	...	...	...	...	...
Weight : 40.65 kgr. (81.94 lb. per yard), profile adopted in 1898.	1 476.8	1924 to 1928	3	...	*3*	178.0	10.47	1919 to 1923	2	5	*7*	147.3	29.53
Medium rails :													
Weight : 50 kgr. (100.79 lb. per yard), profile adopted in 1910.	2 096.6	1924 to 1928	1	10	*11*	1 278.8	5.34	1919 to 1923	7	13	*20*	549.9	22.5
Weight : 52 kgr. (104.82 lb. per yard), profile adopted in 1886.	215.2	...	...	...	...	...	...	...	...	...	...	...	...
Heavy rails :													
Weight : 57 kgr. (114.90 lb. per yard), profile adopted in 1907.	291.9	...	...	...	...	...	...	...	...	...	...	...	...
Total. . .	4 193.7	...	4	10	*14*	...	...	...	9	18	*27*	...	...

Number of English tons (gross) hauled, passengers and goods : 30 387 830 050.

Number of train miles : 43 438 016.

Total number of fractures : 249.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 35.61.

Age of rails :											
15 to 20 years.				more than 20 years.							
Year of manufacture.	Number of fractures.			Year of manufacture.	Number of fractures.			Length of single track with profiles of 15 years and more.	Number of fractures per 1 000 kilometres or per 625 miles of these classes.	Total number of fractures for the whole of the System.	*Maximum axle load.*
	In the length of the rail.	At the joint.	Total.		In the length of the rail.	At the joint.	Total.				
15	16	17	18	19	20	21	22	23	24	25	26
								Miles.			Pounds.
...	...	...	...	...	3	1	*4*	113.2	21.95	*4*	
1909 to 1914	2	8	*10*	1898 to 1908	36	44	*80*	1 151.5	48.56	*100*	
1910 to 1914	7	33	*40*	...	...	...	...	267.9	92.80	*71*	44 090
...	...	...	...	1887 to 1908	7	11	*18*	215.2	51.94	*18*	
1908 to 1914	17	39	*56*	...	...	...	...	291.9	119 22	*56*	
...	26	80	*106*		46	56	*102*	...	...	*249*	

Percentages of fractures :	At the joint.	Outside the joint.
I. *Light rails*	55.76	44.24
II. *Medium rails*	78.87	21.13
III. *Heavy rails*	69.64	30.36

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load*
Chimay Railway.	No fractured rail was reported.															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
French Nord Railway (Nord Belge Lines).		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Light rails	...	...	...	...	...	...	...	3.89	...	...	1.57	...	...	7.96	...	18.2
Medium rails	...	74.89	...	...	7.09	...	1	12.33	50	...	50.95	...	3	40.50	46	19.7
Heavy rails	...	...	...	...	...	...	...	...	...	...	1.39	...	...	1.42	...	19.7
Total. . .	...	74.89	...	...	7.09	...	1	16.22	38	...	53.91	...	3	49.88	37	...

Number of train-miles : 2 156 484.
Total number of fractures : 4.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles ; 12.

PARTICULARS OF THE FRACTURES.

Medium rails.

Rails from 10 to 15 years of age

1 failure at the joint : fracture with old part much rusted not extending to the outer surface of the head ; number of pieces 2.

Rails more than 20 years of age :

1 fracture, outside the joint and between sleepers, with old part much rusted not extending to the outer surface of the head ; number of pieces : 2.

1 failure at the joint : fresh and clean breakage over the whole of the rail section without oval mark ; number of pieces : 2.

1 failure at the joint : fracture showing old part much rusted, extending to the outer surface of the head ; number of pieces : 2.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Belgian National Light Railway Company. (*)																English tons.
Light rails	...	...	...	1 (at the joint)	...	...	...	...	...	65 (at the joint)	...	...	543	292 at the joint 251 outside the joint.		9.8
Medium rails	...	...	...	16 (at the joint	...	...	...	...	...	...	...	...	...	...	...	...
Total. . .	...	...	...	17	...	...	...	...	...	65	...	...	43	...	...	...

(*) On part of system only (2 246 miles).

Number of train-miles : 24 973 340.
Total number of fractures : 625.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 155.

Compagnie belges de Chemins de fer et d'Entreprises. — Owing to the little importance of the system operated, this Company is unable to supply any useful information.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CONGO COLONY.		Miles.						Miles.			Miles					English tons.
Lower-Congo to Katanga Railway.																
a) Bukama-Sakania line.																
Light rails	3	62	30	...	...	...	6	200	19	15	236	40	...	...	...	13.8

Number of train-miles : 1 704 450.
Total number of fractures : 24.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 88

Notes. — Percentage of fractures : at the joint 18 %; outside the joint 82 %.
Percentage of breakages according to the appearance of the fracture : a—2 = 5, or 21 %; b 1 = 5, or 21 %; b—2 = 1, or 4 %; c = 13, or 54 %.
Length of line : 802 km. (498 miles).

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Miles.			Miles.											English tons.
b) Port Francqui-Bukuma line.															
Light rails	1	573.5	1	1	124.3	5	...	...	...	...	...	...	...	...	...	10.5 (Loc. 98)

Number of train-miles : about 372 800 (provisional operation).
Total number of fractures : 2.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 33.

Both fractures occurred outside the joint. With regard to the appearance of the fracture, they may be classed under B. *c*.
Length of line : 697.8 miles.

Upper Congo tho the Great African Lakes Railway.

No rail fractures in 1928.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CHINA.		Miles.			Miles.			Miles.			Miles.			Miles.		Pounds
South Manchuria Railway Company.																
Light rails	6	10.9	342.5	30	67.4	276.4	50	74.9	414.6	7	66.6	65.4	22	42.3	319.6	51 235
Medium rails	88	398.1	137.3	41	399.3	137.9	...	...	...	...	...	...	...	...	...	51 235
Total . . .	94	409.0	142.8	71	466.7	94.5	50	74.9	414.6	7	66.6	65.4	22	42.3	319.6	...

Number of train-miles : 8 624 095.
Total number of fractures : 244.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 175.8.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
DENMARK.		Miles.			Miles.			Miles.			Miles.			Miles.		
State Railways.																
Light rails	...	65.5	...	6	142.8	26.1	2	153.1	8.1	4	279.4	8.9	186	692.8	166.9	
Medium rails	...	79.4	...	2	163 3	7 6	...	53.4	...	2	140 4	8.9	4	98.8	25.2	
Total . . .	...	144.9	...	8	306.1	16.2	2	206.5	6.0	6	419.8	8.9	190	791.6	149.0	

Number of train-miles : 13 369 000.
Total number of fractures : 206.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 95.9.

DESCRIPTION OF RAILS.	Total number of fractures.	A				B												
		Percentage of fractures at the joint		outside the joint		*a)* 1.		*a)* 2.		*b)* 1.		*b)* 2.		*c)*		*d)* Number of pieces rails broken into		
		number	per-centage	number	per-centage	number	per-centage	number	per-centage	number	per-centage	number	per-centage	number	per-centage	two pieces	three pieces	four pieces
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Light rails.	198	149	75.3	49	24.7	1	0.5	84	42.4	36	18.2	50	25.3	27	13.6	185	11	2
Medium rails.	8	8	100	0	0.0	0	0.0	1	12.5	2	25.0	3	37.5	2	25.0	7	1	0
Total. . . .	206	157	76.2	49	23.8	1	0.5	85	41.2	38	18.4	53	25.8	29	14.1	192	12	2

A. — Percentage of fractures in the respective portions of the rails *covered by* and *clear of* the fishplates.

B. — Percentage of fractures according to the appearance of the fracture :

a) Fresh and clean fracture through the whole of the rail section : 1. With silvery oval mark ; 2. Without silvery oval mark.

b) Fractures, part of which is old and much rusted, extending to the outer face of the foot or head of the rai :

1. When the rusted part is in the foot ;
2. When the rusted part is in the head.

c) Fractures with much rusted portion not extending to the outer face of the foot or head of the rail.

d) Number of pieces into which the rail is broken.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
East of Zealand Railway.														Miles.		Pounds.
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	7	29.2	...	20 720

Number of train-miles : 145 530.
Total number of fractures : 7

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
South Funen Railway.		Miles.						Miles.						Miles.		
Light rails	...	(about) 21.7	...	...	(about) 5.0	...	...	(about) 19.9	...	..	...	...	35	about 82.6	263	...

Number of train-miles : 839 610.
Total number of fractures : 35.
Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 262.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
EGYPT. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	12	620.1	12.02	18.85
Medium rails	...	295.0	...	...	202.6	...	4	150.4	16.52	8	140.9	34.78	4	655.4	3.79	18.85
Total . . .	...	295.0	...	...	202.6	...	4	150.4	16.52	8	140.9	34.78	16	1275.5	7.79	...

Number of train-miles : 12 643 190.
Total number of fractures : 28.
Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 13.97.

TYPE OF RAILS.	On the straight.		On curves.		*Remarks.*
	Number.	Age.	Number.	Age.	
1	2	3	4	5	6
EGYPT. **State Railways.** (*continued*).					
	1	13	...	...	
	1	14	...	...	Stock rail.
	...	...	2	14	Stock rail.
Flat 47 kgr. (96.7 lb. per yard)	1	15	...	...	
	1	15	...	...	Stock rail.
	...	...	1	15	
	...	...	3	15	Stock rail.
	1	17	...	...	
	1	17	...	...	Rail in crossing.
Flat 46 kgr. (92.7 lb. per yard)	1	22	...	...	
	1	22	...	...	Stock rail.
Flat 42 kgr. (84.7 lb. per yard)	...	...	1	23	
	1	26	...	...	
Flat 37.4 kgr. (75.4 lb. per yard)	1	31	...	...	
	1	36	...	...	
	1	36	...	...	
Flat 36 kgr. (72.6 lb. per yard)	...	...	6	36	
	1	37	...	...	
	...	...	1	37	
D. C. 35.7 kgr. (72.9 lb. per yard)	1	42	...	...	

Percentage of fractures at the joint : 3.57 %

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SPAIN.		Miles.												Miles.		English tons.
Andalusian and South of Spain Railways.																
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	And. 128 / South 52	662 / 187	...	...
Medium rails	And. 1	148	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Number of train-miles : { And. : 3 937 113. / South : 934 844.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : { And. : 201.04. / South. : 345.60.

Total number of fractures : {And. : 129. / South. : 52.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Central Aragon Railway.														Miles.		English tons.
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	6	186	...	...

Number of train-miles : 906 800.

Total number of fractures : 6.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Madrid, Saragossa and Alicante Railway.		Miles.			Miles.			Miles							Miles.		English tons.
Light rails :	...	...	...	...	...	...	...	...	...	...	...	...	15	213	43.73	17.7
Medium rails :	3	164.7	11.32	8	279.6	...	1	174	3.60	...	...	...	...	...	...	17.7
Total. . .	3	164.7	11 32	8	279.6	...	1	174	3.60	...	...	...	15	213	43.73	...

Number of train-miles : 19 051 905.
Total number of fractures : 27.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 8.81.

Particulars of the fractures, according to the appearance of the section.

(*Madrid, Saragossa and Alicante Railway*).

A. Percentage of failures at the joint (that is to say in the part of the rail covered by the fishplate) and outside the joint.		*B.* Percentage of failures according to the appearance of the section.					
		a) New clean fracture over the whole section of the rail.		*b)* Fracture partly old and rusted extending to the outer surface of the flange or head of the rail.		*c)* Fracture with old and rusted surface not extending to the exterior surface of the flange or of the head of the rail.	*d)* Number of pieces into which the rail was broken.
At the joint.	Outside the joint.	1. With silvery oval mark.	2. Without silvery oval mark.	1. Rusted surface in the flange of the rail.	2. Rusted surface in the head of the rail.		
...	100.0	...	43.75	31.25	25.00	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	Maximum axle load.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
North of Spain Railway.		Miles.			Miles.			Miles.			Miles.			Miles.		Pounds
Light rails	...	...	...	2	1 041.0	1.19	...	...	...	1	1 041.0	0.60	67	1 041.0	39.99	38 580
Medium rails	19	1 677.5	7.03	3	1 677.5	1.11	11	1 677.5	4.07	7	1 677.5	2.60	...	...	...	38 580
Total. . .	19	...	...	5	...	...	11	...	...	8	...	...	67	...	...	...

Number of train-miles : 19 442 280.
Total number of fractures : 110.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 35.15.

Mines and Railway of Utrillas.

No fractured rails in 1928.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Great Southern of Spain Railway.														Miles.		Pounds
Light rails	1	...	...	...	...	...	...	...	...	...	...	...	13	123	66	30 645

Number of train-miles : 455 100.
Total number of factures : 14.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 191.

1	Rolled : 1924-1928.			Rolled : 1919-1923.			Rolled : 1914-1918.			Rolled : 1909-1913.			A. S. C. E. rail.			
UNITED STATES OF AMERICA. Baltimore and Ohio Railroad.	2	3 Miles.	4	5	6 Miles.	7	8	9 Miles.	10	11	12 Miles.	13	14	15	16	17 Pounds
100 lb. per yard rails.	264	1 625	102	195	975	125	311	740	263	125	173	452	15	86	109	70 000
130 lb. per yard rails.	85	743.4	71.5	12	115.2	65	...	...	...	...	...	...	...	...	...	70 000

The information given includes ninety-seven 130-lb. rails and nine hundred and ten 100-lb rails as coming under the general term *broken rails*. The following tabulations show the percentage of broken rails to all failed rails, and also divides them into four classes, according to the location and nature of the break :

130 lb. per yard rail.	Number.	Per cent.
A. Plain clear breaks outside splice bars	9	3.5
B. Transverse fissures	54	21.0
C. Plain clear breaks inside splice bars	9	3.5
D. Diagonal breaks at joints through web and head	25	9.7
E. Split web failures outside splice bars	6	2.3
F. Crushed and split heads	151	58.8
G. Broken bases	3	1.2
Total	257	100.0

Failures classed under headings *A*, *B*, *C* and *D*, a total of 97 or 37.7 % of all 130-lb. rail failures, are included in the report.

100 lb. per yard rail.	Number.	Per cent.
A. Plain clear breaks outside splice bars	185	12.1
B. Transverse fissures	326	21.3
C. Plain clear breaks inside splice bars	116	7.6
D. Diagonal breaks through web and head at joints	283	18.5
E. Split webs outside splice bars	78	5.1
F. Crushed and split heads	530	34.7
G. Broken bases	9	0.1
Total	1 527	100.0

Failures classed under headings *A*, *B*, *C* and *D*, a total of 910 or 59.5 % of all 100-lb. rail failures, are included in the report as broken rails.

The classification of the failures as given is in accordance with the instructions contained in the final summary adopted by the London Congress, except that our records have not been kept in such detail as to sub-divide broken or transverse fissures according to the degree or extent of the oxidation.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km or per 625 miles.	10 to 15 years. Number of fractures	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Delaware and Hudson Railway.		Miles.			Miles.			Miles.			Miles.			Miles.		Pounds
Medium rails	98	340	180	36	383	58	29	67	270	14	70	125	7	33	132	75 000

Number of train-miles : 3 700 000.

Total number of fractures : 184.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 310.

1	2	3	4	5	6	7	8	9	10	11	12	1	14	15	16	17
Lehigh & New England Railroad.		Miles.			Miles.			Miles.								Pounds
Medium rails	2	36	34	3	39	47	7	53	82	...	...	...	...	...	...	73 000

Number of train-miles : 550 526.

Total number of fractures : 12.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 136.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	ROAD.	Age of rails: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
New York Central Lines.			Miles			Miles.			Miles.			Miles.			Miles		Pounds
Light rails	New York Central-East	...	...	...	19	370.60	32.00	22	358.22	39.00	19	421. 63	28.00	...	312.36	...	...
	New York Central West	...	...	...	...	...	...	...	4.00	...	1	20.00	31.25	1	5.00	125.00	...
	O. C. Lines.	...	...	...	...	...	...	2	1.40	893.00	3	13.51	139.00	...	...	...	...
	Rutland	...	...	...	...	...	...	...	...	...	2	37.16	33.64	17	97.84	108.60	57 200
Medium rails	New York Central-East	130	1 027.77	80.00	145	1 445.68	63.00	114	762.76	94.00	51	163.37	195.00	...	19.40	...	64 000
	New York Central-West	14	659.00	13.28	21	949.00	13.83	2	331.00	41.54	9	147.00	38.27	...	51.00	...	65 000
	O. C. Lines.	10	289.92	22.00	7	133.67	33.00	11	31.50	218.00	...	22.22	...	...	2.54	...	..
	Boston & Albany.	41	302.36	84.75	31	86 19	224.79	...	...	...	...	...	...	...	...	...	...
	Pittsburgh & Lake Erie	...	...	...	...	...	...	...	15.27	...	...	6.45	...	...	...	...	...
	Cleveland, Cincinnati, Chicago & St. Louis	41	804.00	31.87	75	789.00	59.41	...	...	...	...	...	...	...	...	...	...
	Michigan Central.	52	385.68	84.27	207	588.78	219.73	...	...	...	...	...	...	...	...	...	62 000
	Indiana Harbour Belt	3	37.85	49 00	...	27.32	...	...	...	...	...	...	...	...	0.23	...	60 000
	Rutland	3	122.68	15.28	...	97.25	...	...	52.93	...	1	17.79	35.13	...	...	...	57 200
Heavy rails	New York Central-East	50	484.28	65.00	12	29.72	253.00	...	...	...	...	...	...	...	...	...	64 000
	New York Central-West	3	325.00	5.77	...	16.00	...	...	...	...	...	...	...	...	...	...	65 000
	Pittsburgh & Lake Erie	...	216.52	...	6	199.28	18.67	...	...	...	...	...	...	...	...	...	62 500
	Michigan Central.	...	166.85	...	...	...	...	...	...	...	...	...	...	...	...	...	62 000
	Cleveland, Cincinnati, Chicago & St. Louis	...	16.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...

ROAD.	Total number of fractures.	Number of fractures per 10 000 000 trains-kilometres or 6 250 000 train-miles.
New York Central-East	562	94.00
New York Central-West	71	20.88
New York Central - O. C. Lines	33	63.00
Boston & Albany.	72	85.00
Pittsburg & Lake Erie.	6	12.53
Cleveland, Cincinnati, Chicago & St. Louis	116	50.58
Michigan Central	259	114.0
Indiana Harbour Belt	3	4.63
Rutland	23	78.04

Note. — No failures on Chicago Junction Railway.

The information submitted above, as in past years, covers rail fractures which have developed in as many as twelve different rail sections of varied design and composition, as well as manufacture. The rails, of course, are located in tracks over which all types of service are operated, both light and heavy traffic, slow and high speed tracks, on tangents and curves of various degrees, and with varying subsoil and ballast conditions.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles	Maximum axle load
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Miles.			Miles.			Miles.			Miles.			Miles.		Pounds.
Norfolk & Western Railway.																
Light rails: 85 lb. per yard	...	...	...	...	...	...	...	...	...	...	14	...	2	238	5.3	Steam locomotives: 68 000.
Medium rails: 100 lb. per yard	6	187	20.1	13	457	17.8	16	266	37.6	1	176	2.8	...	...	...	
Heavy rails: 130 lb. per yard	20	1 077	11.6	4	157	16.0	...	...	...	...	...	...	...	...	...	Electric locomotives: 75 000.
Total. . .	26	1 264	12.8	17	614	17.3	16	266	37.6	1	316	2.8	2	238	5.3	

Number of train-miles: 14 989 913.

Total number of fractures: 62.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles: 25.6.

1 Pennsylvania Railroad.	2	3 Miles.	4	5	6 Miles.	7	8	9 Miles.	10	11	12 Miles.	13	14	15 Miles.	16	17 Pounds
Light rails :	...	...	...	...	...	...	...	...	...	243	156.96	967.6	724	1 267.18	357.09	76 100
Medium rails :	78	1 064.98	45.78	230	620.04	231.84	1006	1 995.05	315.15	1090	1 819.83	374.35	860	2 801.53	191.86	76 100
Heavy rails :	317	3 294.85	60.13	610	2 185.03	174.48	443	830.11	333 54	2	4.96	252.2	...	0.25	...	78 500
Total. . .	395	4 359.83	56.63	840	2 805.07	187.16	1449	2 825.16	320.56	1335	1 981.75	421.03	1584	4 068.96	243.30	...

Number of train-miles : 120 590 381.
Total number of fractures : 5 603.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 290.39.

	Fractures		Broken into						
	In joint. %	Silvery oval spot. %	2 pieces. %	3 pieces. %	4 pieces %	5 pieces. %	6 pieces. %	8 pieces. %	14 pieces. %
Light rails :	84.38	3.52	88.22	10.86	0.72	0.10	...	...	0.10
Medium rails :	72.76	11.89	87.26	11.40	1.07	0.15	0.09	0.03	...
Heavy rails :	72.67	18.66	91.19	8.16	0.58	0.07	...	...	...
All rail.	74 75	12.10	88.38	10.51	0.89	0.12	0.06	0.02	0.02

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			*Maximum axle load*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Reading Company.																
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Medium rails	4	...	...	6	...	...	8	...	...	3	...	...	4	...	...	...
Heavy rails	17	..	...	24	...	...	...	...	...	...	...	...	...	...	...	...
Richmond, Fredericksburg and Potomac Railroad.		Miles.			Miles.											Pounds
Medium rails	...	48	..	2	103	12	...	...	...	...	...	...	...	...	...	69 900
Heavy rails	8 (1)	77	65	...	...	...	...	...	...	...	...	...	...	...	...	69 900
Total . .	8½	125	40	2	103	12	...	...	...	...	...	...	...	...	...	...

Number of train-miles: 2 503 776.
Total number of fractures: 10.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 trains-mile: 25.

(1) The large number of fractures in the heavy rail, which in this particular case is 130-pound section, was due to defective rails from two ingots of a particular heat.

Wabash Railway.	2	3 Miles	4	5	6 Miles.		8	Miles.	10	11	12 Miles.	13	14	15 Miles.	16	17 Pounds
Light rails	...	...	...	...	...	...	1	1.4	446	29	23.6	770	539	875.8	382	67 500
Medium rails	30	338.76	55	88	429.90	130	137	205.86	411	81	161.30	305	1	55.3	110	67 500
Heavy rails	13	344.28	24	...	....	...	...	...	...	...	...	...	...	...	...	67 500
Total . . .	43	683.04	39	88	429.90	130	138	207.26	410	110	184.90	310	540	931.10	333	...

Number of train-miles : 15 290 876.
Total number of fractures : 919.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 374.

Number of fractures occurring in splice : 310 — 34 %.
Number of fractures occurring out of splice : 609 — 66 %.

Includes all main line failures regardless of nature of defect.

1 FINLAND. State Railways.	2	3 Miles.	4	5	6 Miles.	7	8	9 Miles.	10	11	12 Miles.	13	14	15 Miles.	16	17 English tons.
Light rails	101	486.5	129	2	139.8	8.9	...	316.9	...	5	368.5	8.4	136	2 595	32.8	14.8
Medium rails.	2	52.2	23.8	1	118.0	5.3	...	71.5	...	...	...	...	...	...	...	14.8
Total. . .	103	538.7	118.8	3	257.8	7.2	...	388.4	...	5	368.5	8.4	136	2 595	32.8	...

Number of train-miles : 12 381 625.
Total number of fractures : 247.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 124.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Age of rails : Less than 5 years.	5 to 10 years.	10 to 15 years.	15 to 20 years.	More than 20 years.	Length of single track.	Number of fractures per 1000 km. or per 625 miles.	Maximum axle load.
1	2	3	4	5	6	7	8	9
FRANCE. State Railways.						Miles.		English tons.
Light rails	...	...	...	19	187	5 566	23	19.7
Medium rails	4	4	2	14	52	2 480	19	19 7
Heavy rails : Standard 55 kgr. per m. (111.87 lb. per yard).	...	1	...	...	...	50	12	19.7
Total . . .	4	5	2	33	239	...	...	...

Number of train-miles : 41 477 524.
Total number of fractures : 283.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 42.4.

	Percentage : Covered by the fishplates.
A. — Fractures of light rails.	25.2
— medium	73.7
— heavy	100

	Percentage : Clear of the fishplates.
A — Fractures of light rails	74.8
— medium	26.3
— heavy.	...

		Light.	*Medium*	*Heavy.*
		Per cent.	Per cent.	Per cent.
B. — a) Fresh and clean fracture in the whole of the rail section. . .	with silvery oval mark. . .	8.2	6.6	...
	without silvery oval mark	29.1	22.4	...
b) Fracture, part of which is old and much rusted, extending to the outer surface of the foot or the head of the rail	in the foot.	24.3	11.8	...
	in the head	14.1	10.5	...
c) Fracture, part of which is old and much rusted, not extending to the outer surface of the foot or the head of the rail	. . . . .	24.3	48.7	100

		2 pieces.	3 pieces.	4 pieces	5 pieces.	6 pieces	7 pieces
d) Number of pieces into which the rail is broken	light	190	10	2	4	...	...
	medium. . .	63	9	4	...	...	...
	heavy . . .	...	1	...	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			Maximum axle load
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Alsace and Lorraine Railways (including the Guillaume-Luxembourg lines).		Miles.			Miles.			Miles.			Miles.			Miles.		English tons
Light rails	...	...	...	...	27.3	...	6	139.2	27	8	182.7	27	95	1 212.1	49	For wagons : 15.7. For locomotives : 18.3.
Medium rails	1	308	2	2	141.7	9	21	69.0	189	9	122.4	46	20	117.4	106	
Heavy rails	...	2	...	...	...	...	...	...	...	...	...	...	...	..	...	
Total . .	1	310	2	2	169.0	7	27	208 2	81	17	208.1	35	115	1 329.5	54	...

Number of train-miles : 19 696 066.
Total number of fractures : 162.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 51.

Note. — This table does not include broken *machined rails* in points and crossings, that is to say, those of the nose, wing rails, points and stock rails.

	Percentage : Covered by the fishplates.
A. — Fractures of light rails	82.6
— medium	94.3
— heavy	...

	Percentage : Clear of the fishplates.
A. — Fractures of light rails	17.4
— medium	5.7
— heavy	...

		Light.	*Medium.*	*Heavy.*
		Per cent.	Per cent.	
B — a) Fresh and clean fracture in the whole of the rail section	with silvery oval mark	11.6	3.8	...
	without silvery oval mark	22.0	26.4	...
b) Fracture, part of which is old and much rusted, extending to the outer surface of the foot or the head of the rail	in the foot	9.2	5.7	...
	in the head	21.1	15.1	...
c) Fracture, part of which is old and much rusted, not extending to the outer surface of the foot or the head of the rail	in the web	36.7	49.0	...

		2 pieces	3 pieces	4 pieces	7 pieces	9 pieces
d) Number of pieces into which the rail is broken	light	82	20	5	1	1
	medium	36	14	3	...	...
	heavy	...	...	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles	More than 20 years Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles	*Maximum axle load*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Paris Circle Railways. (*)																
Light rails.	...	1.03	...	...	8.38	...	...	1.81	...	1	18.36	34	...	18.25	...	
Medium rails.	...	69.53	...	...	29.69	...	...	5.82	...	1	2.83	219	4	0.87	2 865	18.9
Heavy rails	...	3.82	...	...	1.27	...	...	...	...	...	...	...	...	...	...	
Total. . .	...	74.38	...	...	39.29	...	...	7.63	...	2	21.19	58	4	19.12	130	

(*) Broken rails in main lines (excluding those in points and crossings).

Number of train-miles : 2 385 150
Total number of fractures : 6.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 19.45.

	Percentage : Covered by the fishplates.
A — Fractures of light rails	100.00
— medium	100.00
— heavy	...

	Percentage : Clear of the fishplates.
A. — Fractures of light rails	...
— medium	...
— heavy	...

		Light.	*Medium.*	*Heavy.*
		Per cent.	Per cent.	
B. — *a* Fresh an clean fracture in the whole of the rail section .	with silvery oval mark . .	...	...	...
	without silvery oval mark .	...	...	...
Fracture, part o which is old and much rusted, extending to the outer surface of the foot or the head of the rail	in the foot	100	...	...
	in the head	...	40	...
c) Fracture, part of which is old and much rusted, not extending to the outer surface of the foot or the head of the rail . . .	. . . . .	...	60	...

		2 pieces.	3 pieces.	4 pieces.
d) Number of pieces into which the rail is broken	light	1	...	...
	medium	5	...	...
	heavy	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Est Railway. (*)		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Light rails	...	55.0	...	1	112.2	5.5	...	114.3	...	1	138.0	4.5	211	2 604.2	50.3	
Medium rails	...	481.6	...	4	351.7	7	5	323.7	9.5	23	333.3	42.8	86	1 304.9	40.9	18.3 (locomotives).
Heavy rails . .	...	14.9	...	...	6.8	...	...	...	...	...	...	...	...	...	...	
Total. . .	...	551.5	...	5	470.7	6.6	5	438.0	7	24	533.3	27 9	297	3 909.1	47.2	

(*) Fractures in main lines, excluding points and crossings.

Number of train-miles : 37 640 697.
Total number of fractures : 331.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 54.64.

	Percentage: Covered by the fishplates.
A. — Fractures of light rails	17.4
— medium	81.4
— heavy	...

	Percentage: Clear of the fishplates.
A. — Fractures of light rails	82.6
— medium	18.6
— heavy	...

		Light.	*Medium.*	*Heavy.*
		Per cent.	Per cent.	
B — a Fresh and clean fracture in the whole of the rail section.	with silvery oval mark	15.9	22.9	...
	without silvery oval mark	49.7	37.3	...
b) Fracture, part of which is old and much rusted, extending to the outer surface of the foot or the head of the rail.	in the foot.	14.6	5.08	...
	in the head	11.3	9.32	...
c) Fracture, part of which is old and much rusted, not extending to the outer surface of the foot or the head of the rail	in the web	8.5	25.4	...

		2 pieces.	3 pieces	4 pieces.	5 pieces.	7 pieces.	12 pieces.
Number of pieces into which the rail is broken.	light	202	4	4	1	1	1
	medium	72	20	1	5	...	...
	heavy	...	...	...	..	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Midi Railway. (*)		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Light rails	...	4.3	...	...	...	...	...	...	...	11	262.8	26	55	2 124 5	16	17.7
Medium rails.	2	406.4	3	16	493.4	20	5	119.3	26	...	...	...	...	...	...	17.7
Heavy rails	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	17.7
Total. . .	2	410.7	3	16	493.4	20	5	119,3	26	11	262.8	26	55	2 124.5	16	...

(*) Main lines.

Number of train-miles : 20 463 823.
Total number of fractures : 89.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 27.

	Percentage : Covered by the fishplates
A. — Fractures of light rails	45
— medium	100
— heavy	...

	Percentage : Clear of the fishplates.
A. — Fractures of light rails	55
— medium	...
— heavy	...

		Light.	*Medium.*	*Heavy.*
		Per cent.	Per cent.	
B. — a) Fresh and clean fracture in the whole of the rail section	with silvery oval mark	13.6	4.4	
	without silvery oval mark	36.4	34.8	
b) Fracture, part of which is old and much rusted, extending to the outer surface of the foot or the head of the rail	in the foot	12.1	30.4	None.
	in the head	10.6	8.7	
c) Fracture, part of which is old and much rusted, not extending to the outer surface of the foot or the head of the rail		27.3	21.7	

		2 pieces.	3 pieces.	4 pieces.	6 pieces.	7 pieces.	8 pieces.	9 pieces.	11 pieces	14 pieces	17 pieces
d) Number of pieces into which the rail is broken	light	48	8	1	1	1	1	2	1	2	1
	medium	18	2	2	...	1	...	...	...	...	...
	heavy	...	...	...	...	...	...	...	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nord Railway.		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Light rails	...	...	...	...	201.3	...	7	154.7	28.1	2	36.7	33.9	87	794.1	68	18.5
Medium rails	1	428.7	1.4	9	523.8	10.7	6	464.8	8	13	431.9	18.7	34	921.5	22.9	18.5
Heavy rails	...	2.4	...	...	1.9	...	...	0.05	...	...	...	...	...	...	...	18.5
Total . . .	1	431.1	1.4	9	727.0	7.7	13	619.55	13	15	468.6	19.9	121	1 715.6	43.8	...

Number of train-miles : 36 976 110

Total number of fractures : 159.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 27.

	Percentage: Covered by the fishplates.
A. — Fractures of light rails	38.5
— medium	57.1
— heavy	...

	Percentage: Clear of the fishplates.
A. — Fractures of light rails	61.5
— medium	42.9
— heavy	...

		Light.	*Medium.*	*Heavy.*
		Per cent.	Per cent.	
B. — *a*) Fresh and clean fracture in the whole of the rail section	with silvery oval mark	7.3	12.7	...
	without silvery oval mark	30.2	23 8	...
b) Fracture, part of which is old and much rusted, extending to the outer surface of the foot or the head of the rail	in the foot	32.3	20.7	...
	in the head	13.5	23.8	...
c) Fracture part of which is old and much rusted, not extending to the outer surface of the foot or the head of the rail	in the web	16.7	19.0	...

		2 pieces.	3 pieces.	4 pieces.
d) Number of pieces into which the rail is broken	light	80	12	4
	medium	49	12	2
	heavy	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Age of rails :					Length of single track.	Number of fractures per 1000 km. or per 625 miles.	Maximum axle load.
	Less than 5 years.	5 to 10 years.	10 to 20 years.	15 to 20 years.	More than 20 years.			
1	2	3	4	5	6	7	8	9
Paris-Orleans Railway.						Miles.		English tons.
Light rails	...	1	4	1	39	3 919	7.1	18.7
Medium rails.	6	23	4	3	39	2 178.5	17.1	18.7
Heavy rails : Standard [55 kgr. (110.9 lb. per yard].	1	1	...	...	...	62.8	2.0	18.7
Total . .	7	25	8	4	78	...	...	...

Number of train-miles : 38 712 284.
Total number of fractures · 122.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 19.

	Percentage : Covered by the fishplates.
A. — Fractures of light rails	25.0
— medium	37.5
— heavy	...

	Percentage : Clear of the fishplates.
A — Fractures of light rails	75.0
— medium	62.5
— heavy	...

		Light.	*Medium.*	*Heavy.*
		Per cent.	Per cent.	
B. — a) Fresh and clean fracture the whole of the rail section	with silvery oval mark	4.4	24.0	...
	without silvery oval mark	40.0	29.3	100
b) Fracture, part of which is old and much rusted, extending to the outer surface of the foot or the head of the rail	in the foot	8.9	18.7	...
	in the head	24.5	18.7	...
c) Fracture, part of which is old and much rusted, not extending to the outer surface of the foot or the head of the rail		22.2	9.3	...

		2 pieces.	3 pieces.	4 pieces.	5 pieces.	6 pieces.	More than 6 pieces.
d) Number of pieces into which the rail is broken	light	41	1	2	...	1	...
	medium	58	13	3	...	1	...
	heavy	2	...	...	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			Maximum axle load
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Paris, Lyons and Mediterranean Railway. (*)		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Light rails	...	213.1	...	...	122.4	...	...	113.1	....	7	337.4	12.89	215	3 538.4	37.12	18.2
Medium rails	5	833.3	3.73	27	433.7	38.68 (1)	15	751.3	12.40	71	1 245.2	35.43	140	1 589.5	54.73	
Heavy rails	1	23.0	27.02	...	...	...	...	...	...	...	...	...	...	...	...	
Total. . .	6	1 069.4	3.48	27	556.1	30.16 (2)	15	864.4	10.78	78	1 582.6	30.62	355	5 187.9	42.52	

(*) Broken rails, excluding those in points and crossings.

Number of train-miles : 70 796 597.
Total number of fractures : 481.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 42.21

(1) 17 of these in tunnels on 23 miles of single line, that is a proportion of 459.45 per 1 000 km. or 625 miles, the proportion of 38.68 being reduced to 15.12 outside tunnels.

(2) 17 of these in tunnels on 26.1 miles of single line, that is a proportion of 404.76 per 1 000 km. or 625 miles, the proportion of 30.16 being reduced to 11.72 outside tunnels.

PARIS, LYONS AND MEDITERRANEAN RAILWAY.

Table I.

	Fractures covered by the fishplates.		Fractures clear of the fishplates.	
	Number.	Percentage.	Number.	Percentage.
Light rails	86	38.74	136	61.26
Medium —	200	77.52	58	22.48
Heavy —	1	100.00	...	...

Table II

	Fresh and clean fractures through the whole of the rail section.		Fractures partly old.	
	Number.	Percentage.	Number.	Percentage.
Light rails	122	54.96	100	45.04
Medium —	146	56.59	112	43.41
Heavy —	1	100.00	...	...

Table III.

	Rails broken into :									
	2 pieces.		3 pieces.		4 pieces.		5 pieces		6 pieces.	
	Number.	Per-centage.	Number.	Per-centage.	Number.	Per-centage.	Number.	Per-centage.	Number.	Per-centage.
Light rails . . .	172	77.48	35	15 77	12	5.40	2	0.90	1	0.45
Medium — . . .	177	68.61	42	16.28	27	10.47	10	3.87	2	0.77
Heavy — . . .	1	100.00	...	...	...	...	...	...	...	...

Table IV.

	Fresh and clean fractures through the whole of the rail section.				Fractures with old part extending to the outer surface				Fractures with much rusted old part not extending to the outer surface of the foot or the head.	
	With oval mark.		Without oval mark.		of the foot.		of the head.			
	Number.	Per-centage.	Number.	Per-centage.	Number.	Per-centage.	Number.	Per-centage.	Number.	Percentage.
Light rails . .	15	6.76	107	48.20	24	10.81	39	17.57	37	16.66
Medium — . .	9	3.46	137	53.11	26	10.08	28	10.86	58	22.49
Heavy — . .	...	...	1	100.00	...	...	...	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	Maximum axle load.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
														Miles.		English tons.
Bouches-du-Rhône Departmental Railways and Electric Tramways.																
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	6	123.3	30.23	14.8
Number of train-miles : 250 854. Total number of fractures : 6.										Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 148.6						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
														Miles.		English tons.
Tarn Departmental Railways.																
Light rails	...	...	...	...	...	...	...	...	...	..	...	...	...	93.2	...	7.9
Light Railways of the Landes.																
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	11	225.6	30.3	14.3
Number of train-miles : 362 152. Total number of fractures : 11.										Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 188.						

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Somain-Anzin-Frontière belge Railway.											Miles.			Miles.		
Light rails.	1	7.7	...	..	...	...	...	...	...	2	3.4	...	2	7.2	...	...

Number of train-miles : 494 322.
Total number of fractures : 5.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 62.

Sud-Ouest Railway.

No fractured rails reported in 1928.

Deux-Sèvres Departmental Tramways.

No rail breakages occurred on this system in 1928.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Indre Tramways.														Miles.		English tons.
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	20	114.3	108	8.1

Number of train-miles : 242 536.
Total number of fractures : 20.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 512.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			Maximum axle load
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ALGERIA AND TUNIS.								Miles.						Miles.		English tons.
Algerian State Railways Algiers District.																
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	10	311.9	...	13.8
Medium rails	...	...	...	...	...	...	...	94.4	...	...	...	...	...	...	...	13.8
Total . . .	...	...	...	...	...	...	...	94.4	...	...	...	...	10	311.9	...	...

Number of train-miles : 2 280 315.
Total number of fractures : 10.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 27.249.

A. — Percentage of fractures in the respective portions of the rails :
1. Covered by the fishplates . . . . . 40 %
2. Clear of the fishplates. . . . . 60 %

B. Fractures according to the appearance of the fracture :
a) Fresh and clean fracture through the whole of the rail section :
1. With silvery oval mark . . . . . 12 %
2. Without silvery oval mark. . . . . 38 %

b) Fractures, part of which is old and much rusted extending to the outer surface of the foot or head of the rail :
1. Rusted part in the foot . . . . . 20 %
2. Rusted part in the head . . . . . 30 %

c) Fractures with much rusted portion not extending to the outer surface of the foot or head of the rail . . 0 %

d) Number of pieces into which rails broken. . . . . up to 5

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Bône District.		Miles			Miles			Miles.						Miles.		English tons.
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	18	182.7	61	13.8
Medium rails	...	15.9	...	...	43.4	...	...	32.3	...	...	...	...	...	...	...	13.8
Total . . .	...	15.9	...	...	43.4	...	...	32.3	...	...	...	...	18	182.7	61	...

Number of train-miles : 1 674 232.
Total number of fractures : 18.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 66.7.

A. — Percentage of fractures in the respective portions of the rails :

1. Covered by the fishplates. . . . . 16.7 %
2. Clear of the fishplates . . . . . 83.3 %

B. — Fractures according to the appearance of the section :

a) Fresh and clean fracture through the whole of the rail section :

1. With silvery oval mark . . . . . 27.8 %
2. Without silvery oval mark . . . . . 66.7 %

b) Fractures, part of which is old and much rusted, extending to the outer face of the foot or head of the rail :

1. Rusted part in the foot. . . . . 5.5 %
2. Rusted part in the head . . . . . None.

c) Fractures with much rusted portion not extending to the outer face of the foot or head of the rail. . None.

d) Number of pieces into which the rail is broken : 2 for each fracture.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Constantine District.		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Light rails	...	58.4	...	1	0.6	1000	...	19.3	...	1	106.9	5.81	16	369.7	26.88	(1)
Medium rails.	...	8.1	...	...	0.6	...	...	15.5	...	...	...	...	...	...	...	13.8
Total. . .	...	66.5	...	1	1.2	500	...	34.8	...	1	106.9	5.81	16	369.7	26.88	...

Number of train-miles : 2 071 229.
Total number of fractures : 18.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 54.

A. — Percentage of fractures in the respective portions of the rails :
1. Covered by the fishplates . . . . . 33.33 %.
2. Clear of the fishplates . . . . . 66.67 %.

B. — Fractures according to the appearance of the section :
a) Fresh and clean fracture through the whole of the rail section . . . . . 27.77 %.
1. With silvery oval mark
2. Without silvery oval mark
(This information cannot be supplied).

b) Fractures, part of which is old and much rusted, extending to the outer surface of the foot or head of the rail :
1. Rusted part in the foot . . . . . 5.55 %.
2. Rusted part in the head. . . . . 55.55 %.

c) Fractures with much rusted portion not extending to the outer surface of the foot or head of the rail. . 11.11 %.

d) Number of pieces into which the rail is broken :
2 for each fracture.

(1) 9.4 for 2 fractures; 13,8 for 16 fractures.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
					Miles.									Miles.		English tons.
Oran District.																
Light rails.	...	...	...	1	822	0.755	...	...	...	...	...	...	37	822	27.966	10.4

Number of train-miles : 1 904 065.
Total number of fractures : 38.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 124.011.

A. — Percentage of fractures in the respective portions of the rails :

1. Covered by the fishplates . . . . . 2 6 %
2. Clear of the fishplates. . . . . 97.4 %

B. — Fractures according to the appearance of the section :

a) Fresh and clean fracture through the whole of the rail section . . . . . 86.9 %

1. With silvery oval mark
2. Without silvery oval mark

(This information cannot be supplied).

b) Fractures, part of which is old and much rusted, extending to the outer surface of the foot or head of the rail :

1. Rusted part in the foot . . . . . 10.5 %
2. Rusted part in the head. . . . . 2.6 %

c) Fractures with much rusted portion not extending to the outer surface of the foot or head of the rail . . . .

d) Number of pieces into which the rail is broken ; 2 pieces for each rail.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Maximum axle load.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Paris, Lyons and Mediterranean Railway (Algerian system).		Miles.			Miles.			Miles.			Miles			Miles.			English tons.
Light rails.	...	6.2	...	...	149.1	...	...	95.7	...	3	98.8	19	14	382.1	23	16.39
Medium rails.	...	28.6	...	...	26.7	...	...	1.2	...	...	...	...	...	...	...	16.39
Heavy rails.	...	1.2	...	...	...	...	...	...	...	...	...	...	...	...	...	16.39
Total. . .	...	36.0	...	...	175.8	...	...	96.9	...	3	98.8	19	14	382.1	23	...

Number of train-miles : 2 417 016.
Total number of fractures : 17.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 43.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Gafsa Railway.														Miles.		English tons.
Light rails.	...	...	...	...	...	...	...	...	...	...	...	...	2	151	8.23	9.8

Number of train-miles : 990 835.
Number of train-miles since the line was open 30 years ago : 17 098 753.
Total number of fractures : 2.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 12.51.

A. — Percentage of fractures in the respective portions of the rails :

1. Covered by the fishplates . . . . . 50 %
2. Clear of the fishplates . . . . . 50 %

B. — Fractures according to the appearance of the section :

a) Fresh and clean fracture through the whole of the rail section :

1. With silvery oval mark . . . . . 50 %
2. Without silvery oval mark . . . . . None.

b) Fractures, part of which is old and much rusted, extending to the outer surface of the foot or head of the rail :

1. Rusted part in the foot . . . . . 50 %
2. Rusted part in the head. . . . . None.

c) Fractures with much rusted portions not extending to the outer surface of the foot or head of the rail. . None.

d) Number of pieces into which the rail is broken :
2 pieces for the rail broken in the part covered by the fishplates and 3 pieces for the fracture clear of the fishplates.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			Maximum axle load
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Tunisian Railways.		Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Light rails :																
20 kgr. (40.32 lb. per yard) (narrow gauge)	...	...	...	...	...	...	...	...	...	...	...	...	7	145.66	21.334	11.81
25 kgr. (50.40 lb. per yard) (standard gauge) . . .	...	...	...	...	...	...	...	...	...	...	...	...	4	4.57	544.437	14.76
25 kgr. (50.40 lb. per yard) (narrow gauge). . . .	...	...	...	...	...	...	...	...	...	2	364.40	3.410	30	364.40	51.155	11.81
30 kgr. (60.48 lb. per yard) (standard gauge) . . .	...	...	...	...	...	...	...	...	...	...	152.44	...	...	...	...	14.76
30 kgr. (60.48 lb. per yard.) (narrow gauge). . . .	...	...	...	...	...	...	...	158.26	...	...	...	...	...	...	...	11.81
34 kgr. (68.54 lb. per yard) (standard gauge) . . .	...	...	...	...	...	...	...	...	...	...	...	...	8	29.99	165.759	14.76
38.20 kgr.(77.01 lb. per yard) (standard gauge) . . .	...	...	...	...	107.49	...	...	...	...	...	...	...	...	...	...	14.76
Medium rails :																
46 kgr. (94.21 lb. per yard (standard gauge) . . .	...	20.84	...	...	...	...	...	...	...	...	...	...	...	...	...	14.76
Total. . .	...	20.84	...	...	107.49	...	...	158.26	...	2	516.84	2.404	49	544.62	55.905	...

Number of train-miles : 3 230 550.
Total number of fractures ; 51.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 98.009.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails :									FRACTURES				APPEARANCE OF THE FRACTURES							
	Less than 5 years.			5 to 20 years.			More than 20 years.			Covered by the fishplates.		Clear of the fishplates.		Fresh and clean fracture in the whole of the rail section.		Fracture, part of which is old and much rusted					
																extending to the outer surface of the foot or the head of the rail.				not extending to the outer surface of the foot or the head of the rail.	
																RUSTED PART					
																in the foot.		in the head.			
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number.	Percentage.	Number.	Percentage.	with silvery oval mark.	without silvery oval mark.	Number	Percentage.	Number	Percentage.	Number	Percentage.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
								Miles.													
COLONIES AND PROTECTORATES.																					
AFRICA.																					
French West African Railways.																					
***a*) Thiès to the Niger.**																					
Flat, 20 kgr. (40.32 lb. per yard), 6 m. (19 ft. 8 1/4 in.) long.	...	...	...	...	...	...	43	368.5	79.18	3	6.97	40	93.02	2	1	32	74.41	4	9.30	4	9.30
Flat, 25 kgr. (50.40 lb. per yard), 8 m. (26 ft. 3 in.) long.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Flat, 26 kgr. (52.41 lb. per yard).	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Total. . .	...	...	...	...	...	...	43	368.5	79.18	3	6.97	40	93.02	2	1	32	74.41	4	9.30	4	9.30

Maximum axle load : 9.8 English tons.

Number of train-miles : 1 491 691.

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 179.11.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
		Miles.			Miles.			Miles.								
								More than 10 years.								
b) Conakry to the Niger Railway.	No fractured rails in 1928.															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
c) Ivory Coast Railway.																English tons.
Light rails :																
Flat, 19 ft. 8 1/4 in. long . .	...	...	...	...	...	...	1	182.69	...	...	...	...	...	...	...	Golwé engines: 11.8 per axle. 13.7 when fully loaded.
Flat, 26 ft. 3 in. long . . .	...	...	...	...	20.19	...	...	12.43	...	...	...	...	...	...	...	
Flat, 32 ft. 9 3/4 in. long . .	...	...	...	..	1.80	...	...	...	...	...	...	...	...	...	...	
Standard, 26 ft. 3 in. long . .	...	12.67	...	...	...	...	...	...	...	...	...	...	...	...	...	
Standard, 39 ft. 4 1/2 in. long .	...	73.38	...	...	...	...	...	...	...	...	...	...	...	...	...	
Weight per metre (per yard): Flat, 25.5 kgr. (51.4 lb.) Standard, 26.1 kgr. (52.6 lb.)																
Total. . .	...	86.05	...	...	21.99	...	1	195.12	...	...	...	...	...	...	...	...
Number of train-miles : 539 939.													Total number of fractures : 1.			
d) Dahomey Railways. (East Dahomey.)	No fractured rails in 1928.															
French Dahomey Railway Company. (Central Dahomey.)	No fractured rails in 1928.															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ASIA MINOR.																
Damas-Hamah and Extensions Railway.														Miles.		English tons.
Light rails	...	...	...	...	...	...	...	...	...	...	...	...	2 (1)	91.22	13.6	12.48
													1 (2)	206.02	3	12.99
													...(3)	63.56	...	...
Total. . .	...	...	...	...	...	...	...	...	...	...	...	...	3	...	...	...
Total number of train-miles : Beyrouth-Damas : 507 239. Rayak-Halep and Homs-Tripoli : 264 549 771 788													Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 24.15.			
Total number of fractures : 3.																

(1) Beyrouth-Damas line : 27.620 kgr. (55.7 lb. per yard) rails. — (2) Rayak-Halep line : 30 kgr. (60.5 lb. per yard) rails. — (3) Homs-Tripoli line : 30 kgr. (60.5 lb. per yard) rails.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
INDO-CHINA								Miles.			Miles.			Miles.		English tons.
Indo-Chinese Colonial [illegible] **Railways.**																
Light rails	...	...	...		...	...	1	25	25	3	188.9	9 87	16	392.1	25.35	10.3

Number of train-miles : 2 513 400.
Total number of fractures : 20

Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 49

Characteristics of the fractures.	Number of fractures.	Percentage.
A. — Fractures in the respective parts:		
1. Covered by the fishplates.	6	30
2. Clear of the fishplates	14	70
B. — *a*) Fresh and clean fracture in the whole of the rail section:		
1. With oval mark	1	5
2. Without oval mark	6	30
b) Fracture, part of which is old and much rusted, *extending* to the outer surface of the foot or the head of the rail:		
1. Rusted part in the foot	4	20
2. Rusted part in the head	7	35
c) Fracture, part of which is old and much rusted, *not extending* to the outer surface of the foot or the head of the rail	2	10

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS	Age of rails: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	Maximum axle load.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Indo-China & Yunnan Railways.		Miles.									Miles.			Miles.		English tons.
Light rails	...	14.44	...	...	...	...	...	...	.. { 17 broken. 42 cracked }	225.41	{ 46 broken. 115 cracked.	{ 5 broken. 6 cracked.	{ 290 19	{ 10 broken. 12 cracked.	10.6	
Number of train-miles : 1 732 949. Total number of fractures : 22 rails broken ; 48 cracked.										Number of fractures per 10 0 0 000 train-kilometres or 6 250 000 train-miles : 78 fractures ; 171 cracks.						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Reunion Island Railway.		Miles.			Miles.						Miles.			Miles.		English tons.
Light rails	...	21 75	...	...	9.32	...	...	...	...	...	24.85	...	20	23.11	...	5.4
Number of train-miles : 231 593.																

Note. — These statistics will be concluded in the number for November next.

Hardening of steel in the Wild-Barfield electro-magnetic furnace.

Figs 1 to 6, p. 2095 to 2097.

(*Le Génie Civil.*)

The exact determination of the moment when a piece of steel which is being heated has just reached its transformation point is an everyday problem for manufacturers who have to harden pieces of steel, since hardening failures are almost always due to errors in heating. If heating is insufficient, certain portions of the pieces are hard and others are soft, resulting in an insufficient average hardness. If, on the contrary, the steel is over-heated, the grain is coarse and the excessive amount of cementite dissolved in gamma iron causes a reduction in strength. The most serious point is that these defects do not appear on the surface of the pieces; steel hardened at a high temperature has no blemishes, is hard to the file and gives satisfactory results with most testing machines, but at the end of a short time, the tool breaks or is deformed.

For a long time it has seemed that the exact determination of the temperature of the pieces undergoing treatment was a sufficient condition for obtaining correct hardening, whence the use of pyrometric methods. The most perfect pyrometer, however, only indicates the temperature of the heating chamber or, very approximately, that of the surface of the piece. It will never indicate the temperature of the core of the piece, which, however, is the only temperature that counts in obtaining correct hardening.

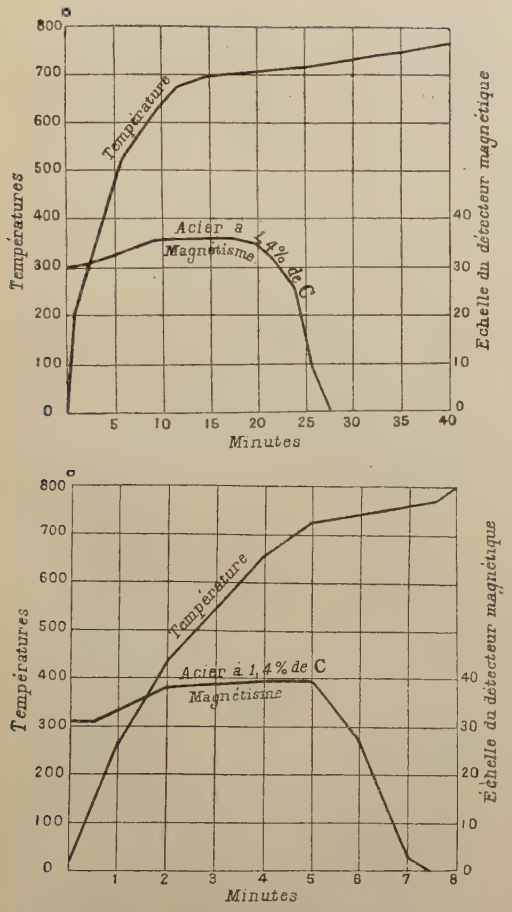
Moreover, this temperature, even if known exactly, cannot be a sufficient indication, because the critical temperature *varies with the rate of heating*, and not merely, as is often believed, with the composition of the steel and the degree of work-hardening. The moment at which the steel should be quenched is that at which it has just reached a certain state, determined by a special arrangement of its constituents, a state which only lasts for an instant, and of which advantage must be taken to cool the piece quickly.

This state is not always reached at the same degree of temperature. The curves (figs. 1 and 2) illustrate this, and also provide some idea of the order of magnitude which may be attained by the variations due solely to the differences in the rate of heating for a steel containing 1.4 % carbon. The two samples were taken of course from the same piece of steel, and in order to ensure exactness of the temperature determination, the pyrometer couple was inserted inside the steel. The steel was correctly hardened in both cases, although the hardening temperature varied by 30° C. (86° F.), by no means an exceptional figure.

Thus, hardening based on the measurement of temperature can only give very mediocre results. In most cases, the pieces are over-heated.

Two phenomena of a physico-chemical nature accompany the passage of steel through its critical temperature :

a) The loss of its magnetic properties, which loss is complete the exact moment the steel reaches its critical temperature;



Figs. 1 and 2. — Variation of the magnetism of a steel with the rate of heating.

Explanation of French terms: Acier à 1.4 % C. = Steel with 1.4 % carbon. -- Échelle du détecteur magnétique = Scale of magnetic detector — Magnétisme = Magnetism.

b) A reduction in the rate of heating at a moment when the hardening temperature is still far from being reached.

Some metallurgists have thought to determine the hardening temperature by noting this second phenomenon by means of a recording pyrometer, the pointer of which indicates a deviation on the temperature-time curve (fig. 3). As previously stated, however, this moment is far in advance of the passage of the steel through the critical point, and there is just the same uncertainty as with the ordinary pyrometer. That is why it is preferable to base the observations on the first-mentioned phenomenon, i. e., the complete loss of magnetism, which for most steels coincides with the critical point (Ac2 point, or Curie point). In point of fact, what it is necessary to ascertain is the exact moment at which the change in structure is accomplished (solution of the cementite in γ iron).

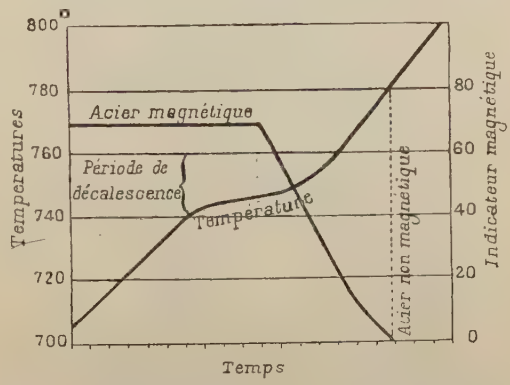


Fig. 3. — Comparison of the temperature-time and magnetism-time curves, showing that a certain time elapses between the end of decalescence and the complete disappearance of magnetism.

Explanation of French terms: Acier magnétique = Magnetic steel. — Acier non magnétique = Non-magnetic steel. — Indicateur magnétique = Magnetic indicator. — Période de décalescence = Period of decalescence.

For all steels containing more than 0.35 % carbon, that is to say, all the carbon steels used in industry, this coincidence is perfect. It only ceases for alloys containing more than 2 % chromium or 5 % tungsten, such as high speed tool steels, which are hardened at much higher temperatures than their transformation point.

Using as a basis these principles, which were enounced in 1897 by Ro-

berts-Austen and later confirmed by Honda and by the greatest metallurgists of England, America and France, the English physicist Wild, in collaboration with Mr. Barfield, has designed an industrial apparatus capable of indicating the hardening point of steel in an exact and automatic manner.

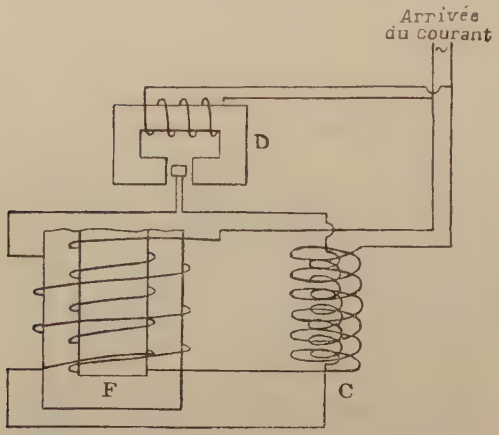


Fig. 4. — Wiring diagram of a Wild-Barfield furnace.

Explanation of French terms:
Arrivée du courant = Current supply.

Description of the furnace. — The Wild-Barfield electromagnetic furnace for the automatic hardening of steels (figs. 4 to 5), is composed substantially of two sets of windings F and C (fig. 4) connected in opposition, the electromotive forces of which are equal and opposite.

The double winding C forms the « compensator ». It has a movable iron core so that its induction may be adjusted and made equal to that of the furnace. Under these conditions, the magnetic detector D, placed in series with the furnace windings and the compensator, remains at zero, at least while the furnace is empty.

If a piece of magnetic steel is introduced into the furnace, the effect of the presence of this mass is to increase the mutual inductance of the winding F. Equilibrium is then upset, and the pointer of the magnetic detector moves under the action of the F current, which has become greater than the C current. If, however, the piece of steel is introduced into the hot furnace, its temperature will rise, and tend to become in

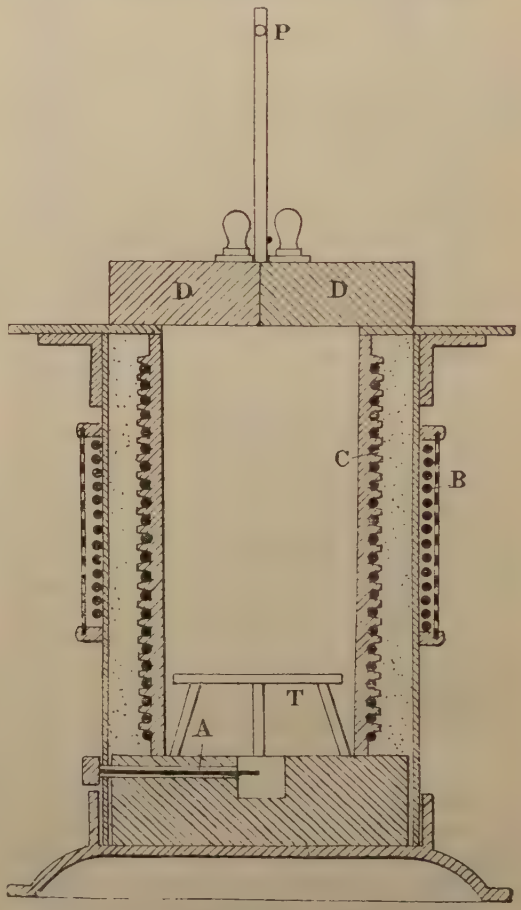


Fig. 5. — Vertical diagrammatic section of a Wild-Barfield furnace.

Legend : A, Temperature limiting fuse.
B, Winding of the magnetic detector.
C, Heating winding of the furnace chamber.
D, Cover in two parts.
E, Rod for suspension of the charge.
F, Tripod supporting the charge.

equilibrium with that of the furnace. At a certain moment, the steel piece will pass through the Ac1 point, beyond which its magnetism diminishes. The pointer of the magnetic detector thus gradually returns to its initial position, which it reaches when the piece, whose temperature always continues to rise, arrives at the Ac2 point, beyond which all trace of magnetism disappears.

Steel which has just reached its transformation point is in the best condition for giving a perfect hardening. In this method, it is certainly the core of the piece which affects the detector, without the intervention of the temperature of either the piece or the furnace.

Figures 5 and 6 show the actual construction of a vertical type of furnace; there is also a horizontal type.

Tests. — The following are some results of comparative tests of hardening by the Wild-Barfield and by the pyrometric method.

In carrying out the tests on the samples heated in the Wild-Barfield furnace, a cylindrical, vertical type apparatus was used, without any apparatus for making pyrometric measurements.

For the samples treated by the pyrometric method, gas furnaces and platinum-rhodium thermo-electric couples were used.

Hardness.

1. *Semi-hard steel* (C = 0.6 Mn = 0.22 Si = 0.15 W = 0.3);

Diameter of sample, mm. (inches)	20 (25/32")	40 (19/16")
Brinell hardness, before hardening	213	213
id., after hardening, using Wild-Barfield furnace	655	660
id., after hardening, using gas furnace	640	600

2. *Hard steel* (C = 1 % Mn = 0.1 Si = 0.1 W = 0.3);

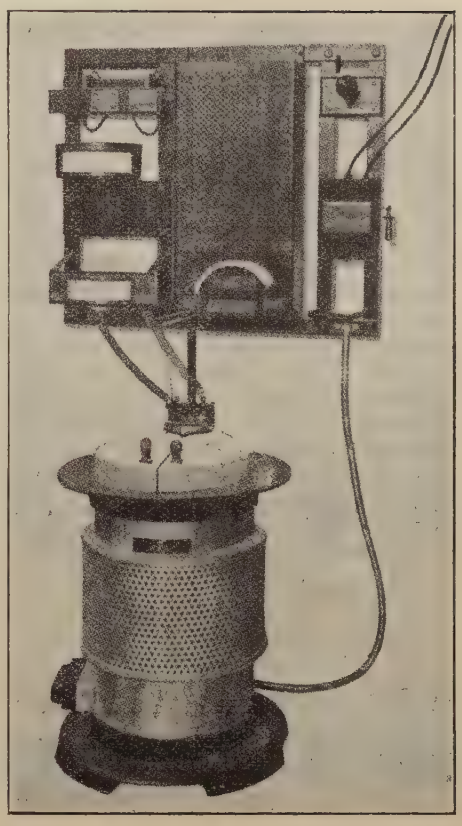


Fig. 6. — Wild-Barfield furnace in front of its control panel.

In the middle of the panel is seen the rheostat for regulating the heating current, on the right-hand side, the circuit breaker, on the left hand side the cases of the pyrometer and the magnetic detector.

Diameter of sample, mm. (inches)	25 (63/64")	40 (19/16")
Brinell hardness, before hardening	275	275
id., hardness, after hardening, using Wild-Barfield furnace	570	700
id., after hardening, using gas furnace	508	506

Deformation. — Measurements carried out on the above-mentioned samples show that a cylindrical bar 20 mm. in diameter remains cylindrical with a diameter of 20.066 mm. if it is heated in the Wild-Barfield furnace; when heated in the gas furnace it does not remain cylindrical and the diameter varies from 20.005 mm. to 20.08 mm.

Brittleness. — The Cadillac Motor Company ascertained that if 936 foot-pounds are required to fracture the tooth of a gear wheel hardened by the ordinary method, 1 820 foot-pounds are required to break a tooth of a gear wheel hardened by the Wild-Barfield method.

From the figures given above, it follows that the advantages of the Wild-Barfield method are more pronounced, the larger the diameter of the samples. This shows that it is the core which is heated, and the exactitude of the heating temperature explains the absence of deformation.

The method is not solely adapted for laboratory tests, because the Wild-Barfield furnace is an industrial apparatus, which is robust, well lagged, and protected by an aluminium casing, and which may be operated by an unskilled workman. It is provided with a silver fuse automatic temperature-limiting device, which interrupts the current if the temperature of the furnace accidently rises above 960° C. (1 728° F.) (a red lamp is then lit and warns the operator). Moreover, it has been adopted in most of the heat treatment shops of the large works.

Ch. D.

NEW BOOKS AND PUBLICATIONS.

[625. 233]

BÜTTNER (Max), Dr. phil. — **Die Beleuchtung von Eisenbahn-Personenwagen (The lighting of railway carriages)**, 4th edition. — One vol. (9 × 6 1/4 inches) of 195 pages with 128 figures. — 1930, Berlin, Julius Springer, publisher. (Price, bound : 15 Rm.).

This book is the fourth edition, entirely revised, of a classical and much appreciated work on the lighting of passenger trains and in particular on the electric lighting of carriages. After a short introduction on the history of the development of train lighting, the author succinctly recalls in the first half of the book the arrangements for lighting: 1. by means of candles, or oil or petrol lamps; 2. by oil-gas, by coal-gas, by acetylene (Piutti lighting, or else dissolved acetylene), all of which systems tend to disappear in face of the generalisation of electric lighting.

The second half of the work dwells in a detailed manner on the systems of lighting by electricity. The first chapter contains a study of accumulators : lead accumulators, nickel-iron and nickel-cadmium accumulators; the second chapter deals with their utilisation for the lighting of carriages. The systems of lighting by means of a dynamo with auxiliary batteries is the subject of the third and most important chapter. It consists of two large subdivisions : I. Lighting of the train by a dynamo worked by a special motor (placed either in the guards-van or on the locomotive); II. Lighting of each coach by a dynamo driven by one of the axles. The author studies in turn the arrangements for the suspension and controlling of the dynamo, the principles of the regulating of its electromotive power and of the lamp voltage; then he passes on to a detailed description of the numerous systems which have been used.

The fourth chapter is concerned with lighting accessories, and the book ends with a study of the advantages and disadvantages as well as the cost-price of the different systems of lighting considered.

A. C.

[385. 091 (5)]

THE RAILWAY GAZETTE. — **First & Second Special Indian and Eastern Numbers.** — Two issues of 152 and 168 pages respectively with coloured map and numerous illustrations and maps. — 1929, published by the Editor of the *Railway Gazette*, 33, Tothill Street, Westminster, London, S. W. 1. (Price of each number : 2 sh. 6 d.).

The *Railway Gazette* has brought out two special numbers devoted to a study of the railways of India and of the Far East countries, notably Ceylon, Malaya, Siam, China and Japan. The information published has been derived from official sources with the assistance and approval of the governments concerned.

They are two voluminous issues generously illustrated. The first deals with the State railways of India and the railways of Malaya and Ceylon. The second describes the railways worked by Companies in India and also the railways of Siam, Japan, Manchuria and China.

The railways of India consist of 41 000 miles of line, of which 30 000 miles belong to the State but only 18 000 miles of which are directly worked by the Indian Government. The State system principally consists of the North West-

ern, the East Indian, the Great Indian Peninsula, the Eastern Bengal and the Burma Railways. The work gives a detailed description of these railways : the country served, the kind of traffic, special working conditions, rates, administrative organisation, stations, workshops. The greater part deals with the Indian railways, but there also chapters dealing more or less extensively with the lesser railways, such as those of Ceylon and Malaya.

A coloured map showing the general distribution of the Indian railways is appended to the two volumes.

The second volume also contains another special map of the company-operated Indian railways. This volume describes the Bombay, Baroda & Central India, the Bengal-Nagpur, the Madras & Southern Mahratta, the South Indian and the Bengal & Nord Western Railways, etc. Among the railways of the Far East dealt with mention must be made of the Royal State Railways of Siam (1 875 miles), the Japanese Government Railways (8 355 miles), the Japanese Colonial Railways, the South Manchuria Railways and the Chinese Railways.

There are very many photographs showing the passenger and goods stations, the permanent way installations, structures, signalling, characteristic types of locomotives and rolling stock, and picturesque views of the country traversed.

These two volumes constitute a document of great value which gives us complete information concerning the development of the railways in the countries concerned.

E. M.

ERRATA

Bulletin, February 1930. Report by Messrs. RIBERA and GARCIA-LOMAS (Question XIX, Madrid Session).

Page $\frac{716}{XIX\text{-}96}$, 2nd column, table :
Instead of « Francs », *read* « Centimes » (Swiss currency).

Bulletin, March 1930. Report by Mr. LIPETZ (Question V, Madrid Session).

Page $\frac{863}{V\text{-}85}$, 1st column, 3rd line of 3rd paragraph :
Instead of « in the World » *read* « in the United States ».

Bulletin, May 1930, page $\frac{1402}{50}$.

Communication from Mr. R. P. WAGNER, Special Reporter on Question VI, Madrid Session :

Our attention has been drawn to an error in our special report on Question VI (Madrid Session). We indicated the maintenance costs of the various types of preheaters as follows :

« 1. Exhaust steam injector, Friedmann : 1.50 fr. per 1 000 train-km. (2.41 fr. per 1 000 train-miles) ;

2. Surface heater, Knorr : 29.15 fr. per 1 000 train-km. (46.90 fr. per 1 000 train-miles) ;

3. Contact heater, ACFI/RM : 21.90 fr. per 1 000 train-km. (35.24 fr. per 1 000 train-miles) ».

and we added :

« It may be safely assumed that the estimate 1) is in gold-francs, whereas 2) and 3) are in French francs. By making the appropriate conversion the actual comparison is found to be :

for 2) : 4.8 gold-fr.
for 3) : 3.43 gold-fr. »

This information should be replaced by that hereafter :

1. Exhaust steam injector, Friedmann : 1.50 French francs per 1 000 tr.-km. (2.41 French francs per 1 000 train-miles).

2. Surface heater, Knorr : 29.15 French francs per 1 000 tr.-km. (46.90 French francs per 1 000 train-miles).

3. Contact heater, ACFI/RM : 21.90 French francs per 1 000 tr.-km. (35.24 French francs per 1 000 train-miles).

Bulletin, August 1930 (Summary of Proceedings, Madrid Session), p. 1836.

Item *a)* of Paragraph 5, Summary, Question II should be worded as follows :

a) *to utilise rails obtained from the head of ingots in those parts of the line which are least heavily stressed.* — The remainder of this item « and to lay them in such a manner that the wheels first run on to them at the end farthest from the ingot head » should be delected.

Bulletin, August 1930 (Summary of Proceedings, Madrid Session — Question IV), p. 1839, 2nd column, 7th line from bottom :

Instead of : ZAVADJIL (Yugoslav State) read : ZAVADIL (Tchechoslovakian Government).